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ANÆSTHETICS

THEIR

USES AND ADMINISTRATION

BY

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PREFACE.

The introduction of anæsthetics, which has done so much to rob surgery of its horrors, alike for the patient and the operator, has created a great demand for persons capable of administering these pain-destroying agents, without unfortunately exciting, as a rule, so great a sense of responsibility in the administrator as his difficult and dangerous duties should render obligatory.

It is surprising that surgeons, who have witnessed the attempts of novices to give anæsthetics, should hold any view save that no one is capable of safely giving any anæsthetic unless he has been carefully taught and has obtained considerable experience.

Personally I do not believe that the perusal of any book will enable a medical man to do more than learn the rudiments of anæsthetising; but a book may be of undoubted service to the thoughtful student or practi-

tioner, in enabling him to appreciate the dangers incident to, the caution necessary in anæsthetising, and to grasp the rationale of the various methods of procedure.

Unfortunately the subject of anæsthetics has for some years escaped the notice of the scientific side of the profession, and as a natural result has been relegated to the domain of routine.

In this book, which has been written purely from the stand-point of every day practice, I have attempted to indicate that the matter dealt with has a scientific as well as a work-a-day aspect, and that he who desires to be more than a mechanical (and hence dangerous) administrator of anæsthetics, must be scientifically as well as practically educated in his art.

82 Mortimer Street,
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ANÆSTHETICS.

CHAPTER I.

Historical.

Means for producing surgical anæsthesia were practically unknown until Wells introduced nitrous oxide, Morton employed ether, and Simpson chloroform. With the first employment of these three agents, commences the history of artificial anæsthesia, although from very early times attempts were made to attain painlessness during surgical operations.

Nepenthes or sedative draughts to relieve severe pain are mentioned in the Odyssey—Helen seeks to "drown all sense of woe" and assuage the sufferings of Menelaus. In Egypt Cannabis Indica, the modern Haschish, and other drugs were similarly used. The Assyrians and ancient Chinese seem to have employed various drugs with a view of relieving the pain of wounds and such rough surgery as was practiced among them. Opium, cannabis indica, carbonic dioxide, and deadly nightshade were advocated in various forms to achieve this object. Pliny and Dioscorides describe several methods in vogue among the Romans and other nations for benumbing parts subjected to incision and cauterisation. Memphis marble, for example, was finely powdered and applied to the part, while on the addition of vinegar a gas was given off (carbonic dioxide) which rendered the part slightly anæsthetic.

Various members of the Euphorbiaceæ, Mandragora, and Solanaceous plants were also employed as infusions, which being drunk induced some narcotism. Attempts at anæsthesia by inhalation were very early practised. The Scythians burned cannabis indica and inhaled its fumes, to alleviate pain.

In more modern times little advance was made until the present century. Most surgeons were contented to put their patients deeply under opium.

In the 16th and 17th centuries Valverdi and others operated upon patients stupefied by compression of the carotid arteries so depriving the brain of blood. James Moore, an English surgeon, in 1784 revived a suggestion originally made by Ambroise Paré that compression of the nerve-trunks should be practised before cutting the areas supplied by them, and John Hunter actually took advantage of the plan and amputated a leg in St. George's Hospital after firmly compressing the crural and sciatic nerves. Mr. Moore expressed himself satisfied with the result. A departure in an entirely new direction was made by Mesmer and his followers, who averred that hypnotised patients could be surgically treated without their experiencing the slightest inconvenience. Dr. Esdaile employed mesmerism somewhat widely in India, and judging from his own statements with considerable success. Hypnotism, however, has never been seriously adopted in this country as a means of producing surgical anæsthesia.

In the 18th century the history of discoveries concerning anæsthetic methods becomes merged in that of the progress of chemical research. Hales, Lavoisier, Priestley and Cavendish opened up rich stores of knowledge by their discoveries among the gases. Oxygen, nitrogen, nitric oxide, were prepared and closely studied,

and in 1772 Priestley added nitrous oxide gas to the list. Pneumatic chemistry, till then unknown, became the absorbing theme among chemists, while physicians sought to bring the recent discoveries to account by pressing these gases into the service of medicine. Dr. Beddoes in 1798, assisted with finances by Wedgwood the renowned potter, inaugurated his Pneumatic Institution at Clifton where he proposed to treat phthisis and many other diseases by inhalations of various gases.

The Pneumatic Institute is interesting mainly because its first superintendent was Humphry Davy, who prosecuted therein his researches concerning nitrous oxide and other gases. In 1799 Davy discovered that "as nitrous oxide, in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place." Davy substantiated his statements by most careful experiments upon the lower animals, extending Hales' research which had been confined to mice, and demonstrating many facts the practical use of which were not appreciated for more than forty years later. But his philosophic mind did not content itself with limiting his experiments here, he actually inhaled the gas and found its influence to assuage the pains of toothache, and in his "Researches" are recorded his own sensations and the behaviour of others after inhaling nitrous oxide gas. Early in the 19th century Dr. Hickman suggested that a painless mode of operating might be achieved by the patients inhaling carbonic acid gas, but Hickman's proposal met scant favour.

The discovery made by Davy was not brought within the field of practical application until Horace Wells

[1844], an American dentist, conceived the idea of using nitrous oxide gas as an anæsthetic for tooth extraction. Wells went to a popular lecture delivered by a Mr. Colton before the inhabitants of Hartford, U.S.A. During the performance one of the audience inhaled an impuer sample of gas and became very excited. In the course of his gyrations this individual wounded his leg but felt no pain, a circumstance of which Wells was not slow to take notice. The following day at the request of Wells, Mr. Colton administered gas to the dentist from whose jaw a Mr. Riggs, another dentist, extracted a molar while Wells was unconscious. After successfully employing gas as an anæsthetic among his own patients, Wells essayed a public demonstration in the operating theatre of the Boston General Hospital. The individual upon whom this experiment was tried was not rendered completely unconscious, and gave unequivocal signs of having felt pain. This failure not only ruined Wells, who died in great poverty not long afterwards, but discredited nitrous oxide as an anæsthetic.

Colton subsequently induced various dentists to experiment, and in 1867 he was able to give a record of 20,000 successful cases. In 1868* nitrous oxide gas was successfully demonstrated at the Dental Hospital of London, and a committee of the leading English dentists was formed. The two reports published by these gentlemen and read before the Odontological Society of Great Britain, spoke in warmest praise of the agent, and practically established its claims as a safe and efficient anæsthetic for short operations.

* Colton while in Paris met with a well known American dentist, Dr. Evans, mainly to whose energy and munificence Colton's apparatus travelled to London, where the merits of nitrous oxide gas were brought before the English faculty.

The discovery of ether as an anæsthetic is also due to American enterprise. It was fairly well known, and its properties recognised as early as 1785, when Dr. Pearson, of Birmingham, employed it as an inhalation for asthma, and early in the present century it was used in the treatment of phthisis. In 1818 a paragraph appeared in the *Journal of Science and the Arts*, which although unsigned is generally supposed to have emanated from the pen of Faraday, it runs: "When the vapour of ether is mixed with common air and inhaled, it produces effects very similar to those occasioned by nitrous oxide." Then follows an account of an experience with ether, a gentleman who inhaled became "lethargic," and so remained for thirty hours. Facts about the narcotic properties of ether were rapidly brought to light, and the writings of Orfila, Brodie, Giacomini, and Christison, all give more or less accurate accounts of the stupefying effects of ether. About the year 1840 it was a common trick at lectures and among medical students to inhale ether vapour in order to induce exhilaration. A number of lads were indulging in this pastime in the outskirts of Anderson, S. C., and to stimulate further their mirth seized upon a negro boy and forced him to inhale ether, pressing the vapour upon him until he became deeply narcotised and apparently dead. In an hour, however, the negro came round to the delight of his tormentors. This scene impressed itself so deeply upon one of the lads named Wilhite, that when three years subsequently he became the pupil of a Dr. Long, of Jefferson, Jackson County, U. S. A., he narrated to him his experiences of ether. As a result Dr. Long in 1842 administered ether to a patient, and while he was narcotised removed a small tumour. The same surgeon employed ether

as an anæsthetic on several subsequent occasions with a like success, but somehow the matter did not attract any particular notice. Other medical men also about this time employed ether for surgical anæsthesia. A student named William Clarke, in 1842, administered ether at Rochester, New York, to a patient for tooth extraction, and Dr. Marcy, an American, operated upon an etherised patient in 1844.

However, the employment of ether as an anæsthetic is more usually associated with the name of Morton, a dentist of Boston. William T. G. Morton was a pupil of Horace Wells, and from his master he gathered his first impressions concerning artificial anæsthesia. It would subserve no useful purpose to open up the miserable quarrels and recriminations which have been connected with Morton and his share in the introduction of ether as an anæsthetic. I will, therefore, merely state the facts as far as I can do so without bias, and after reading both sides of the controversy.

Wells made Morton his partner in a dental business he proposed to start in Boston. The removal from Hartford to Boston was consequent upon a discovery Horace Wells had made of some solder with which he hoped to achieve great things. To confirm his own estimate of the value of this solder he called in a Dr. Jackson, a scientific chemist, who expressed a favourable opinion. However, the partners soon fell out, and Wells returned to Hartford, leaving Morton in Boston. The latter asked Wells for information as to the production of nitrous oxide, and was by him referred to Dr. Jackson. It was suggested by the chemist that trial should be made of sulphuric ether instead of laughing-gas since it was more easily obtained. Acting upon the suggestion, ether was given and teeth were

extracted without pain. This success was followed by a public demonstration, October 17th, 1846, in the Massachusetts General Hospital, when Morton administered ether, and Dr. Warren a well known surgeon proceeded to operate. The experiment was repeated and each time proved a remarkable success.

In England, the first administration of ether took place in Gower Street, London, close to University College Hospital, when Mr. Robertson, a dentist, gave ether and removed some teeth. This took place December 19th, 1846, at the house of Dr. Boot.

On December 21st, Liston amputated through the thigh in University College Hospital, the patient being etherised. Dr. Snow, early in 1847, commenced the successful administration of ether in St. George's Hospital, but upon the introduction of chloroform he gave up ether for its more savoury but less safe rival. On January 19th, 1847, Dr. (afterwards Sir James Young) Simpson administered ether to a woman in childbirth. Notwithstanding favourable experiences of many, ether was not rendered popular for some years subsequently. The methods in vogue for its administration were far from satisfactory, many patients never got beyond the stage of exhilaration and wild excitement, and their struggles and bacchanalian shouts were pronounced highly embarrassing to the presiding surgeon. These considerations led Liston and other eminent surgeons to regard ether with suspicion, and made them diffident in invoking its aid to their assistance. However, up to the time of Simpson's world famed pamphlet, *Notice of a new anæsthetic agent as a substitute for sulphuric ether in surgery and midwifery*, November 1847, ether was slowly but surely winning its way as a safe and trusty anæsthetic. With, however, the in-

troduction of chloroform, came the *coup de grâce* to ether. With an almost incredible rapidity chloroform supplanted her elder sister, not only in Great Britain but almost throughout the world; in America, however, many surgeons still clung to ether. The story of the introduction of chloroform is soon told. Sir James Y. Simpson, not wholly satisfied with ether in obstetric practice, asked Mr. Waldie, the Master of the Apothecaries, Hall of Liverpool, if he, as a practical pharmacist, knew a substance likely to be of service in producing anæsthesia. Mr. Waldie being acquainted with the composition of "chloric ether," suggested that its "active principle," chloroform, should be prepared from it and used. He never carried out his promise to prepare some for him, and so the desired substance was obtained in Edinburgh, and Simpson experimenting found its use perfectly satisfactory. This favourable opinion he expressed in his paper read before the Medico-Chirurgical Society of Edinburgh, Nov. 10th, 1847. It is curious to note how narrowly several persons escaped discovering the value of chloroform as an anæsthetic. Thus, chloric ether, a twelve per cent. solution of chloroform (by volume) in spirits of wine, was employed by Dr. Bigelow, of Boston, but without success. Jacob Bell, of London, however, actually produced insensibility by its use as an inhalation, and Sir William Lawrence, the surgeon, employed it with some success alike in private and hospital practice. Chloric ether was also used at St. Bartholomew's and the Middlesex Hospitals, but the great uncertainty of its action and the expense of procuring large supplies effectually prevented chloric ether from gaining ground as an anæsthetic. Chloroform was experimentally studied by Flourens in 1847, but no practical uses

were made of his work. For some while chloroform was believed to be a "safe anæsthetic," an impression to which the language of Simpson's pamphlet rather lent itself, although certainly no explicit statement to that effect can be found. Unhappily this belief received a rude shock when on January 28th, 1848, a death from chloroform was reported at a place near Newcastle-on-Tyne. This untoward occurrence was soon followed by other deaths and men's minds became anxious. At this pass Snow, with that earnestness and acumen which characterised all he undertook, commenced his researches into the subject.

In 1848, E. Snow published his "experimental papers on narcotic vapours."

Although he improved upon the methods in vogue for the exhibition of ether by the invention of his inhaler, Snow did not advocate at all strongly the merits of that vapour over other narcotics. In 1847 he perfected his chloroform inhaler, being actuated by the belief that this anæsthetic kills through being used in too concentrated a vapour. Snow's experience like that of most others made him regard chloroform as dangerous, and so in 1856 he was tempted to investigate amylene, which he found to deserve his good opinion. A Committee appointed by the Royal Medical Chirurgical Society of Great Britain tendered their report in 1864, which strongly insisted upon the danger of chloroform and the inconvenience of ether as then administered. Therein were embodied many suggestions, some of which Clover, who had then achieved a high reputation as an anæsthetist, was not slow in carrying to a practical issue. In 1862 he had constructed and published an account of his chloroform apparatus by which he regulated the percentage of vapour administered.

Pollock and Warrington Haward in this country were keenly alive to the dangers of chloroform, and they lost no opportunity of urging the use of ether, an advocacy for which we must always feel grateful. But as time went on Clover was less and less inclined to use chloroform. For minor operations he found nitrous oxide gas given by his apparatus to answer best, and he was led to seek some means of prolonging anæsthesia so obtained. This he achieved by the employment of gas and ether, for which combination he soon devised an admirable apparatus, described in the *British Medical Journal* in 1876. Subsequently his "portable regulating ether inhaler" was introduced, and it was mainly by the compactness and efficiency of this instrument that the practical question, how to give ether rapidly and safely, became answered.

It is undesirable to enter further into detail. The subsequent history of anæsthetics is mainly that of attempts to introduce fresh substances or to modify the modes of administering the old ones. But few noteworthy advances can be mentioned; Snow, Clover, Richardson in this country, Claude Bernard, Paul Bert, in France, with others, have devoted much time and labour to the scientific questions connected with anæsthesia, but any account of such labours to be intelligible would occupy more space than can here be devoted to the subject.

CHAPTER II.

Preparation of a Patient and Choice of an Anæsthetic.

Although the anæsthetist seldom has the choice of time given to him, the selection of a suitable hour for the operation is not a matter of indifference in administering an anæsthetic. The effect of anæsthetisation upon the robust may be considered trifling and transient, yet it is not so when the person anæsthetised is an invalid, and either weakly or highly neurotic. Individuals are more liable to after effects of an unpleasant character when their bodily condition is one of nervous exhaustion and lowered vitality. It is then inadvisable unless over-riding circumstances should exist, to give an anæsthetic after a prolonged fast—for instance—in the early morning before food has been taken. Similarly it is inadvisable to select an advanced hour of the evening when the body will be spent with a day of activity or suffering. Further, an anæsthetic should not be given within three hours after a meal of solids, as a full stomach impedes the production of narcosis and leads to vomiting. This last occurring during partial narcosis may occasion fatal accidents through solids being drawn into the trachea. It is well then to select the period of greatest vital activity which is found in most persons in the morning or early afternoon. Arrange for a light meal of soft and easily digested matters to

be taken three hours* before the surgeon should arrive and consisting of milk foods, strong beef-tea, or jellies, etc., varying with the time of the day and the choice of the patient. Weakly persons with feeble heart-action will certainly do well to take a little good brandy or whisky (one or two table-spoonfuls in an equal quantity of milk or water) half an hour or so previously, though it is not wise to make the administration of stimulants before an anæsthetic a matter of routine.

In every instance it is recommended that the bowels should be cleared overnight with a purge. In the case of nitrous oxide these elaborate details may be omitted, still in such an event it is well, with children especially, to see that they pass water before being anæsthetised as urination is often performed unconsciously whilst under the influence of gas.

A patient about to be anæsthetised should be placed in the recumbent position, excepting cases of dental operations under nitrous oxide. The clothing should be carefully loosened, corsets quite undone, neck bands left open and waist belts removed. It is important that your patient be as comfortably posed as circumstances will permit, for while repose of mind and body go far to assist in the production of narcosis, anxiety and uneasiness will greatly retard its accomplishment. He should now be asked to open his mouth and a quick glance given to ascertain if any artificial dentures or an obturator, etc., be worn. Such, if present, must be removed with as little annoyance to the patient as possible. A further step may be taken in reassuring him by a few cheery words, and if necessary, directions as to how he is

* When feasible it is well, unless the patient be in a very feeble state of health, to adopt Clover's rule, and not allow food after five or six hours before the operation.

to take the anæsthetic. Such instructions are often of real service by giving him something about which to think.

When, however, the anæsthetic is once well on the way quietness and silence must be maintained; noise—especially in the case of nitrous oxide—militates considerably against easy and tranquil anæsthetisation.

The choice of an Anæsthetic must depend on

1. The condition of the patient.
2. The necessities of the operation.

Infants and young children bear chloroform well, and are very much terrified by the suffocation of ether or nitrous oxide gas. Ether also in many instances produces much bronchial trouble so that a better anæsthetic for these cases is the A. C. E. mixture or one of chloroform and alcohol. Children above five or six years of age should be given gas and ether unless they are notably the subjects of respiratory trouble. They will probably strongly rebel against having the face piece applied, so that if it be desirable to avoid "a scene" the mixtures of chloroform, alcohol and ether may be substituted and given by the open method. Ethydene dichloride is advocated for children by some, but experience proves that it is not taken more readily and does not appear to be in any way safer in its action than chloroform. Although the use of chloroform is unquestionably attended with happy results in the case of children, it must be remembered that deaths from this agent are by no means confined to adults. It cannot, therefore, be too strongly impressed upon the mind that children run a risk and probably as great a risk in chloroform narcosis as do adults.

Persons of early adult and adult life should have ether given to them, provided always they are free from

pulmonary affections and renal disease. With regard to asthmatics, for those suffering from chronic cough dyspnœa or emphysema the A. C. E. mixture should be tried, but if the ether in this still gives distress its quantity may be decreased, or the Vienna compound used instead. And should the patient suffer greatly from the exclusion of air, through the employment of an inhaler, chloroform can be given by the open method, as that substance will not only produce anæsthesia but will obviate asthmatic seizures. For the subject of chronic bronchial disease the choice of an anæsthetic should be made solely by consideration of his symptoms. In the presence of much dyspnœa, diluted chloroform will be found far preferable to ether. Emphysematous individuals with large (bullock's) hearts are always anxious cases requiring great nicety of treatment. On the one hand lies the possible danger of ether producing a water-logged condition of the rigid chest, and on the other a more than probable danger of syncope through the depressant action of chloroform on the enfeebled, dilated heart. In this dilemma I have found the A. C. E. mixture to answer well, though it needs careful watching as many and grave symptoms may occur during its use. Among persons who have but one available working lung—as when the other is bound by pleuritic adhesions subsequent to effusion—or when one is compressed by an effusion or empyema—the choice of an anæsthetic becomes one of difficulty. In such cases ether is badly borne and chloroform diluted with alcohol is preferable. And again, the heart in these cases being often so pressed upon or displaced is intolerant of further depressing effects,* hence extreme

* Any sudden change in the posture of the patient is dangerous and must be avoided.

caution will be found necessary. Where the kidneys are much damaged and there is considerable danger of suppression of urine, ether is by many held to be contra-indicated. Certainly in many instances no such untoward result has been brought about, still, perhaps it is well to substitute the A. C. E. mixture for ether, for those patients who are the subjects of renal disease.

Arterial disease whether fibroid or due to senile change is a contra-indication for the giving of pure ether. The blood pressure would be increased by this substance, the heart's work augmented and considerable strain imposed upon the diseased arterial walls by which they become in danger of rupture—a result liable to occur in the brain and leading there to the gravest consequences.

For the aged, that is for those over 60 years of age, chloroform is commonly held to be preferable to ether and in many instances this is true. It is, however, true only because persons past middle life are often the subjects of chronic bronchial trouble; they are also frequently diseased in their vascular systems, and upon that account liable to be injuriously affected by ether. Old persons too, like infants, are susceptible to a bronchial and laryngeal irritability which ether excites, producing in some distressing cough, dyspnœa, and exhaustion. However, for aged and feeble subjects with weak hearts and depressed vitality, ether, notwithstanding the drawbacks alluded to above, is beyond doubt the best anæsthetic.

It often becomes a question as to what anæsthetic should be employed in cases of organic heart disease. To answer this question we have to consider firstly, the various forms of valvular disease, and secondly, the conditions of hypertrophy, atrophy, and muscular de-

generation, as well as the pericardial conditions which interfere with cardiac fnnction. Valvular disease of the heart, except when incompetency at the aortic orifice occurs, does not, *per se*, greatly affect the prognosis abont the safety or danger of giving an anæsthetic, although the changes brought about in the vessels, tissnes and organs of the body in general will possibly do so. Indeed it is a fact that in bnt few cases of deaths from an anæsthetic have the valves of the heart been fonnd diseased at the antopsy. When the heart muscle has nndergone structural changes, the danger in prodncing anæsthesia is greatly increased. Any alteration in the respiratory or vascular systems indnced by anæsthetics imposes an extra strain npon the alrcady weakened and diseased heart—one which it is unable to sustain—hence snpervenes syncope. Provided that ether does not interfere with the heart through the lnngs by choking these with secretion, that substance is preferable to chloroform; indeed chloroform given to persons with feeble heart action involves great risk. When ether is contra-indicated on acconnt of lung complication, the A. C. E. mixtnre is preferable to chloroform whether dilnted with alcohol or not.

Hypertrophied hearts are in practice usually *dilated* hearts, and being so are muscnlarly at a disadvantage. The same rules given for guidance above will serve here.

Some highly nervons, excitable persons are mnch terrified by the application of a face-piece, and indeed the mental distress and terror thns excited may be sufficient to occasion serions indisposition. In cases such as these it is especially useful to employ the A. C. E. mixture npon lint, replacing it by ether from Clover's

inhaler so soon as the patient is sufficiently dazed as not to perceive the alteration.

Pregnant women take all forms of anæsthetics well, but if excitable and nervous as they are apt to be, it is better to avoid the coughing and straining which may follow the employment of ether. It will be found, however, that unless very nervous, women in this condition take nitrous oxide followed by ether well—nor are they more liable to after trouble than at other times. In all such instances as little of the anæsthetic should be given as is consistent with true anæsthesia, since it is manifestly important to avoid vomiting.

From the surgeon's point of view—to decide upon the choice of an anæsthetic, is difficult, as it is impossible to lay down hard and fast rules where there will be always conflicting considerations.

Operations about the Head, Face, Trachea and Respiratory Tract.

Brief operations about **the mouth, nose,** or **pharynx,** such as the extraction of teeth, excision of tonsils, opening of abscesses, tearing off mucous polypi, adenoids,* etc., are effectually performed under nitrous oxide. With this agent from 1 to 1·5 minutes of unconsciousness can be assured. If the operation is likely to occupy more than this time and if the cautery is not to be used, gas with ether should be employed, as this combination will prolong anæsthesia. In operations accompanied by severe hæmorrhage but which do not need much time, the gas and ether mixture pos-

* Many specialists prefer chloroform for operations about the nasopharynx.

sesses an advantage inasmuch as the patient rapidly resumes consciousness, and so the fear of blood being drawn through the trachea into the respiratory tract will be avoided. Staphyloraphy necessitates the mouth being open, and it is a matter of consideration that the operator should have free and uninterrupted access to the buccal cavity. To effect this, the patient can be put under the influence of chloroform and maintained so by anæsthetising through the nostril, as described in Chap. V.). The same procedure answers for operations about the tongue.

Removal of the upper or lower jaw should be performed under chloroform, as the cautery is often requisite and the use of a face-piece impossible. In extensive removals of growths about the jaws, it is frequently advisable to perform a preliminary tracheotomy, and then give the anæsthetic through a Trendelenburg's tube.

Operations about the **eyes** require extreme narcosis, absolute immobility and freedom from coughing being essential. Nitrous oxide and ether, provided the ether be pushed very far, answer well; there is of course the possibility of ether exciting a fit of coughing, which should the case be one of excision of a cataract, and should a preliminary iridectomy have been already done, may lead to forcible extrusion of the vitreous. There is less fear of coughing with the A. C. E. mixture.

In excision of the eyeball, where coughing is not of such moment, ether may be used, and should be pushed to deep narcosis before proceeding with an operation. For passing probes or slitting up the lachrymal canals, gas is not satisfactory as the jactitation interferes with the operator, here the use of gas and ether answers every purpose by obviating involuntary movements.

For operations about the **thorax,** a mixture (A. C. E.) is usually more advantageous than chloroform or ether when given alone, so that where there is especial reason for fearing the respiratory difficulty of ether, this agent should be substituted. For the tapping of pleuritic effusion, gas is sufficient.

Abdominal Surgery.

In dissecting operations, when tranquillity of respiration is desired, as in operating for the radical cure of hernia in young children, a mixture, methylene, A.C.E., *et cet.*, must be employed instead of ether, but for all prolonged and exhausting operations, ether should be given unless strongly contra-indicated.

In Labour.

There is a consensus of opinion in favour of chloroform in these cases, based partly upon the assumption that this agent is comparatively safe for parturients, and partly on account of the more agreeable character of the substance. This consideration, however, is open to doubt, for chloroform can be in no way deemed freer from liability to danger in childbirth than at any other time. If chloroform be employed it should not be entrusted to the hands of a nurse or other person unless skilled in its use. The various mixtures answer well in assuaging the pangs of childbed and are probably safer than chloroform. Ether, though advocated by some, is disadvantageous in these cases, as it may provoke

straining, coughing, sickness, and headache,* but for general obstetric operations and especially where the patient is exhausted and needs stimulating, ether may be usefully employed.

* In my private practice I have met with cases of women who after trying chloroform preferred to take ether in their confinements, stating that it produced more exhilaration and general feeling of well-being, while it assuaged their pangs more efficiently than chloroform.

CHAPTER III.

NITROUS OXIDE GAS—LAUGHING GAS OR SIMPLY "GAS."

Chemical and Physical Properties. — NITROUS OXIDE GAS [N_2O] is a colourless body almost devoid of odour. It possesses a neutral reaction and consists of nitrogen and oxygen in chemical union, thus differing from the air which is composed of these gases in mechanical mixture. Nitrous oxide gas possesses well defined anæsthetic properties, which appear to be quite distinct from the asphyxial symptoms frequently accompanying its administration. This gas agrees with oxygen in many of its chemical properties, thus it supports combustion when ignited bodies are plunged into it. At a pressure of fifty atmospheres and a temperature of 44·6° F. (7° C.), it becomes liquefied and advantage is taken of this to enable the gas to be carried about in iron or steel bottles, these latter occupying less space.

Nitrous oxide is decomposed at a red heat but shows no tendency to undergo change at lower levels of temperature. Cold water dissolves more than its own volume of this gas while hot water dissolves less, hence it is advantageous to collect it over water at 15° C. Alcohol takes it up in a still larger proportion.

Preparation. — Granulated nitrate of ammonia is pounded to ensure its being finely divided and is placed in a strong glass retort. One pound of the

salt will make thirty gallons of nitrous oxide gas. The retort is then carefully heated after being connected by tubing with wash bottles as indicated in the figure. At 226° F. the salt melts; at 460° F. it gives off gas, and the temperature must not exceed this by many degrees, otherwise nitric oxide will come over, contaminating the laughing-gas. The nitrous oxide should *bubble* over, not *boil* over, not more than thirty gallons being allowed to volatilise in an hour. Bottle no. 1 nearest the retort, which may with advantage be placed in cold water, answers the

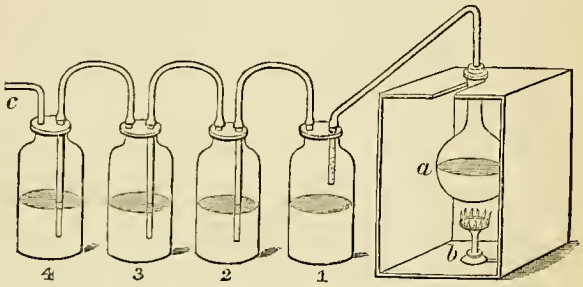

FIG. 1.—Apparatus for the preparation of Nitrous Oxide Gas.

purpose of catching the drippings which come over from the retort; it contains clean cold water almost up to the lower end of the long tube. This tube is perforated in order to break up the gas as it passes over, and to ensure its being washed more thoroughly. In bottle no. 2 about four ounces of ferrous sulphate are placed, and water to a few inches added. Bottle no. 3 contains a stick of potash, and water also added. It is sometimes advisable to use an additional bottle or two containing simply water for washing the gas fur-

ther. Having traversed these bottles the gas is received into the gasometer. When nitrous oxide is stored in bottles, special apparatus will be needed to force the gas in under the pressure of fifty atmospheres.

Purification of nitrous oxide is of undoubted importance, as was shown in the earlier days of anæsthesia, when the most bizarre symptoms were constantly arising, many, if not all of which, were traceable to foreign products being contained in the gas employed.

Much dispute has arisen concerning the propriety of storing gas and keeping it in the liquid state. The obvious advantage accruing from the fact, that when liquefied, it occupies a very small space as compared to its volume when gaseous, is too manifest to need emphasis; the reasons urged against employing any but freshly prepared gas, are firstly, the liquefied gas contains air (Zuntz, Goldstein); secondly, freshly prepared gas is more palatable and less prone to produce headache. My own experience, does not bear out the arguments advanced against liquefied gas, as I have not found discomforts follow its use, save on the rarest occasions, nor have I found the freshly prepared gas more easily taken. At the same time, I must admit that many whose judgment is reliable, speak more favourably of the freshly prepared substance as an inhalation. In what the difference consists it is hard to discover, since chemically, the bottled liquefied gas and that freshly prepared appear identical.

Physiological Action of Nitrous Oxide—The Vegetable Kingdom.

It appears to suspend rather than extinguish vitality. Seeds will not germinate but remain uninjured when kept in it an indefinite period. Seeds, if sprouting, cease to develop when placed in an atmosphere of this gas, but resume their growth when again placed in the air. Jolyet and Blanche found that plants placed in nitrous oxide gas cease to exhale carbonic dioxide and do not increase in size. When oxygen is allowed to mix with the nitrous oxide the seeds germinate, and the plants grow.

The Animal Kingdom.

Cold-blooded animals die in an atmosphere of nitrous oxide in two hours. This contrasts with what obtains when the same creatures are placed in indifferent gases, such as hydrogen or nitrogen, for under these circumstances death does not occur for three hours and is preceded by stupor but not true analgesia. Kappeler has shown that frogs placed in it lose reflexes after a very few minutes, whereas the reflexes persist for several hours when the frogs are placed in an indifferent gas, *e.g.*, nitrogen. Sir Humphry Davy in his careful research showed that small mammals and birds soon die in it, although when it is mixed with oxygen they live until the oxygen tension sinks to 6 per cent., as against a carbonic dioxide tension of 12 per cent. Exposed to such measures the animals remain

sensitive to the last, and it may be stated generally that mixtures of nitrous oxide with other gases under normal pressure are useless for anæsthetic purposes.

In the Human Subject.

It is probable that this gas when administered pure, and not mixed with oxygen, enters the blood by diffusing through the thin walls of the air-cells in the lungs. In the blood, a small quantity is dissolved, but the bulk is connected in some loose way with the blood constituents, probably being associated more or less closely with the albumins and albuminoids of the liquor sanguinis and corpuscles. The effect of shaking arterial blood with nitrous oxide gas is to darken it, showing that nitrous oxide gas is able to displace oxygen. But whatever union does take place is very unstable, as blood parts at once with its nitrous oxide when left in free contact with oxygen or air.

Under nitrous oxide, the respiration becomes slowed and shallow and, if the gas be pushed, a complete cessation of respiratory movements eventually takes place. The amount of tissue change occurring in nitrous oxide narcosis is lessened and so the quantity of carbonic dioxide which the lungs give off is diminished. Subsequently to the administration the exhalation of carbonic dioxide is increased. The heart beats quietly, fully and regularly under this gas, the pulsations are somewhat slowed in profound narcosis. There is, however, but very slight danger of heart failure resulting from inhalation. In animals killed by nitrous oxide gas the heart goes on beating even after the respirations have quite stopped. It is therefore less

important to watch the pulse than the respiration. Blood-pressure is somewhat lowered except in the brain and cord, the vaso-motor system of different areas being, it would appear, diversely affected. This lessened pressure is, however, but slight.

In some observations I made upon this subject, I found that while asphyxia caused diminution of the bulk of the brain and cord, nitrous oxide produces so great an enlargement as to force out the cerebro-spinal fluid. There can be no doubt these changes are vaso-motor in origin, and explain many of the nervous phenomena elicited in persons narcotised by nitrous oxide. The great distension of the vessels must press upon the nerve-cells and fibres both of the brain and cord, and so interfere with their function. (Physiological Action of Nitrous Oxide, *Transactions of Odontological Society*, vol. xix.).

The senses of a person passing under nitrous oxide are at first rendered somewhat more acute, after which follows a condition of unconsciousness to pain. During the first stage of unconsciousness, a loose tooth may be extracted without pain, although the patient has a vague idea that something is being done. A few seconds later, and the individual is profoundly unconscious and insensitive to all his external surroundings. Irregular discharges of nervous energy show themselves at this stage in jactitations of the arms and legs. The limbs are rigid, the rigidity being every second or two broken by a sudden contraction of the flexors. Rhythmic tremors of hands and arms are occasionally elicited. More rarely the whole body of the patient arches forwards like a bow (opisthotonos) jerking him out of the chair. The muscles soon relax and remain flaccid. The degree of rigidity and the amount of jactitation

vary in different cases ; children show jactitation early, and the movements of the limbs are more marked in them than in adults. The superficial reflexes are abolished, that of the patella tendon, however, persists ; and in many cases ankle clonus is developed under nitrous oxide.*

During the condition of hyperæsthesia which precedes anæsthesia, the subject is often affected by hallucinations, frequently of an erotic nature, and the impressions then received remain firmly impressed upon the brain. The difficulty of convincing persons that such impressions are not realities, should lead every administrator to secure independent evidence of his actions while his patient is unconscious. The bladder and even the rectum may be involuntarily emptied under nitrous oxide, and hence it is always wiser to allow patients to pass urine beforehand. As a rule the alimentary tract is unaffected by nitrous oxide, and nausea, vomiting and bilious derangement rarely occur after its administration. However, some persons, through nervousness swallow the gas and this distends the stomach which will give rise to a reflex vomiting. In view of the possible occurrence of this trouble, it is well for patients to abstain from food immediately before taking nitrous oxide gas.

Later effects, which are said in some instances to ensue from the gas, are various functional derangements of the nervous system, paresis of one or more limbs or groups of muscles, paraplegia, hemiplegia, tinnitus aurium, headache and amaurosis.

* For further particulars on this point see a paper by the author on Ankle Clonus under Nitrous oxide, *Brit. Med. Jour.*, Sept. 25th, 1887.

The Administration of Nitrous Oxide Gas and the Purposes for which Applicable.

When used alone, nitrous oxide gas produces a period of anæsthesia, which seldom exceeds a minute and a half or two minutes. Many persons, and especially children, pass out of the condition of unconsciousness with very great celerity, and in them the anæsthetic stage cannot be relied upon for longer than 60 or 75 seconds.

General Surgery.

For the opening of abscesses, whitlows and carbuncles; for the insertion of setons; the tapping of antral abscesses; the removal of portions of the uvula, tonsils, or nasal polyps; for cauterising; and possibly for the passing of Eustachian and other catheters, and the splitting up of the lachrymal canals, nitrous oxide may be used. Tenotomy, divisions of fascias, breaking down adhesions in and about joints and divisions of fistulas may be undertaken with this agent, but as a rule it will be found better in such cases to supplement its use with that of ether.

Many other operations of minor surgery can be carried through under nitrous oxide, and it is possible by judicious management, to prolong anæsthesia for several minutes by administering the gas again and again; such a practice, however, cannot be commended as it is liable to produce headache, faintness, and great discomfort to the patient.

Dental Surgery.

Nitrous oxide alone or combined with a very small dose of ether in the manner to be described hereafter, is the safest and best anæsthetic for this branch of surgery. When nitrous oxide is used alone and pushed to the point of stertor and jactitation, two or three teeth may be extracted at one sitting, and expertness in operating may enable even more to be done. Abnormality of the teeth or mouth may render extraction so difficult as to prevent the successful removal of more than one tooth at a sitting, and in all instances care should be taken to avoid promising the extraction of more than two or three unless the case be manifestly an easy one. If the extracting be kept up too long, pain will be felt, and the patient complain that he could feel the removal of every tooth; to obviate such complaints, an operator would do wisely to place himself in the hands of his anæsthetist, who should generally be better able to judge what may be done with impunity. Unless there exist some special reason for desiring to extract several teeth at one sitting, it is advisable to let the patient attend twice or thrice rather than to subject him to more than one administration on the same day. Extracting a number of teeth simultaneously produces more or less severe shock.

Apparatus Required.

The most convenient and portable apparatus consists of a stand holding a bottle containing fifty gallons of liquefied nitrous oxide gas. Cases are made which hold two of these bottles geared together, so that should one

become empty a supply can be continued from the other.

A most convenient and compact apparatus is shown

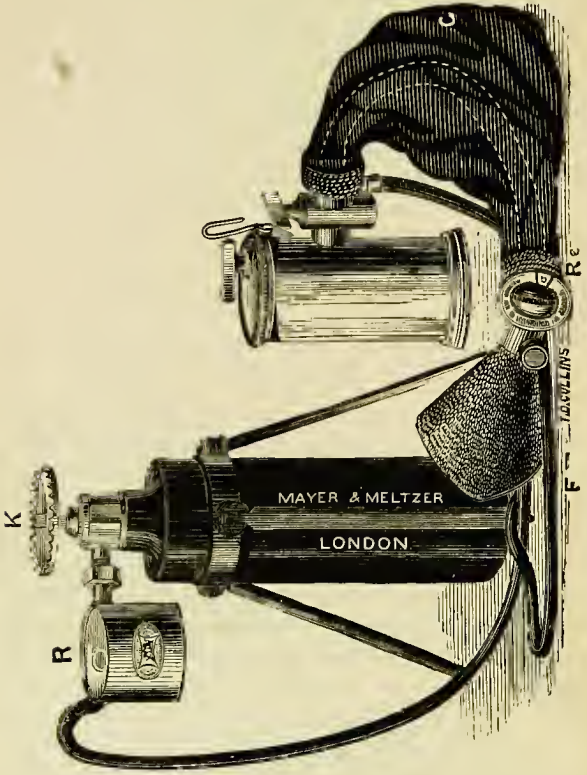

Fig. 2.—Clover's Nitrous Oxide and Ether apparatus.

in the accompanying wood-cut. It consists of a tripod supporting a cast iron bottle containing fifty gallons of nitrous oxide, the bottle being gripped firmly by a screw.

The supply is regulated by the administrator's foot which is placed upon the foot-piece K. This is provided with teeth which bite into the boot and enable the administrator by turning his foot to the left to open the outlet for the gas. R is the connection between the bottle and the Cattlin bag G. The small metallic receiver can be filled with warm water to obviate freezing of the gas in cold weather; it is, however, seldom necessary. The india-rubber tube will be seen to fix on to a stop-cock in front of the ether receiver, which latter is suspended by a hook from the administrator's coat. When only gas is to be given, the stop-cock on the ether vessel is put at right angles to the long axis of the bag; when ether is to be used, this stop-cock is turned into the long axis of the bag. The stop-cock in front of the ether receiver, is more conveniently placed just above where the tube is seen to end. The Cattlin bag is so arranged, as to allow of pure nitrous oxide, pure ether, or a mixture of these two substances to be administered. The supply is regulated firstly by the stop-cocks above mentioned, but more immediately by an arrangement represented, though not very clearly, at *Re*. It consists of a semi-circle of plated metal upon which are engraved at opposite ends, the letters G and E. An indicating rod plays upon this and by simply shifting the indicator so that it revolves free of the semi-disc, air is inspired. When the indicator points to G, nitrous oxide passes into the face-piece and as the indicator travels towards E, ether vapour is permitted to mix with the gas, until arriving fully at E, when pure ether is inhaled.

To complete the description, we have only to mention that the cushioned face-piece used by Clover and supplied with a single expiratory valve is as convenient as any.

Should a supplemental bag be used, the face-piece must be provided with an aperture to which this accessory can be adjusted. The stop-cock in this arrangement is kept shut until the residual air of the lungs is presumably exhausted, when it is opened the finger placed upon the expiratory valve and the patient al-

FIG. 3.—A. Expiratory Valve. B. Inspiratory Tube which gears on on to Cattlin's Bag. C. Supplemental Bag. D. Cap to cover Mount when the Ether or Supplemental Bag is not used.

lowed to breathe backward and forward into the bag. When desirable, however, it is a simple matter to convert the Cattlin bag itself into a supplemental bag, by placing a finger upon the expiratory valve, and so

causing the patient to expire back into the Cattlin as well as inspiring from it.

Where a gasometer is kept, as at the London Dental Hospital, a modification of the above apparatus is in use. A long tube screws on to the efferent pipe of the gasometer, conveying the gas to a bag of 2 or 3 gallons capacity. This may be connected directly with a face-piece or conveyed to it by another length of tubing, and by using a three-way-cock it is easy to combine this apparatus in gear with Clover's smaller ether inhaler (see p. 52). As face-pieces are almost universally employed in the United Kingdom, it is scarcely worth while to describe the mouth-pieces used in America. Briefly, we may say, they are flute-like in shape and are taken between the teeth. The nose is slightly pinched while the patient draws in the gas through the opening in the flute-piece.

Various adjuncts are employed.

Quieters are designed to prevent the hissing of the gas as it rushes from the bottle to the bag.

The employment of supplemental bags has been advocated by Mr. Braine. The bag fits on the face-piece and is guarded by a tap. The patient having presumably emptied his lungs by a few very deep inspirations is allowed to breathe to and fro into the supplemental bag the tap of which is turned to allow gas to enter. The gas supply and the expiratory valve are closed. It may be necessary to empty the bag and refill from the reservoir. Those who employ the supplemental bag claim for it that it is economical and produces a slightly more prolonged period of unconsciousness. The disadvantages are—it is liable to produce headache, it takes longer to get the patient well off, and it is, I believe, opposed to the knowledge we now possess of the physiological ac-

tion of nitrous oxide gas, since it gives a mixed narcosis partly asphyxial and partly due to the gas inhaled.

Another apparatus for the giving of nitrous oxide,

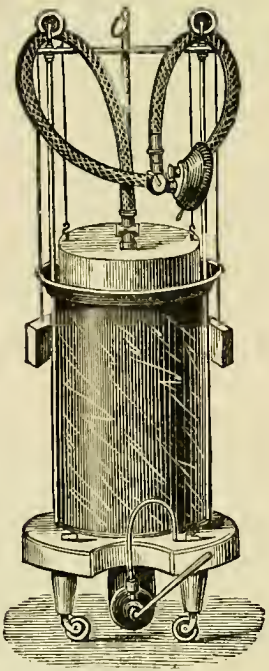

Fig. 4.—Barth's portable gasometer for liquid nitrous oxide.

and one useful to persons who desire to keep a supply always ready in their rooms is figured above.

The Administration.

We will now describe some special manœuvres which are resorted to in the administration of nitrous oxide,

when the mouth is open as is necessary in dental operations. The prop, of which various forms are used, should be carefully fixed in the opposite side of the mouth to that upon which the operation is to take place, and a glance cast round for artificial dentures, or an obturator, which if present must be removed. The patient is now to be reassured by a few cheering words and directed to breathe freely. It is well to allow a nervous subject to take several very deep inspirations before applying the face-piece, as these clear the lungs and divert the attention from a supposed horror of "taking gas." The Cattlin bag is quietly filled by turning the toothed foot-piece under the foot—care being taken to open the way sufficiently and to place the indicator off the plate beyond "G." The face-piece is lightly applied, and retained by just enough pressure to prevent the escape of gas or the entrance of air. In a second or two, the patient becomes accustomed to the face-piece, and is then instructed to take a very deep breath. At this instant the indicator is swiftly turned to the letter "G" and if gas only is to be administered it remains there until the face-piece is about to be withdrawn, when it is pulled off the disc. During the administration it is important to keep the bag full of gas, and to do this the foot must from time to time be turned and gas be allowed to flow from the bottle into the bag. It is well to open the ingress of gas during inspiration and close it during expiration.

After the first fifteen or twenty seconds, that is after the lungs are presumably filled with nitrous oxide, and when gas is gaining tension in the blood, duskiness of the skin appears, the ears and finger tips darken, consciousness, however, being fully present for ten or fifteen seconds longer. In half a minute the patient's

power of receiving impressions and reasoning upon them is greatly interfered with, and in a few seconds more all consciousness is lost. At this stage, incautious acts such as touching the conjunctiva, making loud noises, or roughly handling the patient may lead to his completely regaining consciousness. In from forty-five seconds to a minute, the pupils will dilate, the eyes becoming dull and expressionless, and there may be strabismus. The conjunctival reflex will persist, and if the face-piece be removed at this stage, the return to consciousness will be rapid. There is usually time for the extraction of one tooth, if fairly loose, but not of more. When the inhalation is not checked at this time, further signs of deeper anæsthesia appear. In about a minute and a quarter, the breathing grows stertorous, muscular movements of the hands and feet supervene, and the conjunctival reflex is lost. The eyeballs begin to oscillate, and if the gas be still inhaled the breathing becomes slowed and even intermittent. (Should it stop for more than fifteen seconds (Clover), air must at once be given. At this period of deep anæsthesia there is great stress imposed upon the heart so that the pulse should be watched, and if it flag all further administration should cease). The patient is now ready for operation, and it is not wise to attempt to push nitrous oxide to a greater length.

Further inhalation of gas and air intermittently by means of a tube passed through the nose and down the pharynx has been suggested as enabling the anæsthetist to maintain unconsciousness for operations about the mouth; but it is a method hardly to be commended, and one which presents few if any advantages over that of prolonged anæsthesia with ether impregnating nitrous oxide, as above described.

Patients vary in the time they require to become anæsthetised by nitrous oxide, and even the same individual will differ at various times, being influenced by general health, nervousness, or exhaustion from pain.

The Committee appointed by the Odontological Society of Great Britain found the following averages to obtain :—

	Time Going off.	Duration	Time from Commencement to Recovery.
Males	1 min. 21 sec.	24 sec.	1 min. 55 sec.
Females	1 ,, 16 ,,	28 ,,	2 ,,
Children (under 15)	1 ,, 3 ,,	22 ,,	1 ,, 40 ,,

As a general rule, stertor* or slight jactitation are signs that the patient is ready for operation. In giving nitrous oxide to children, the face-piece should be removed with the very first sign of jactitation, otherwise their small bodies become so convulsed that it is difficult to keep them still for operation, and valuable time is lost in the attempt to place them in a convenient position. It is important to be able to recognise the tokens of returning consciousness so as to know when to desist from further operative measures, and this can usually be done with certainty. In the first place, the normal colour of the face returns, the lips change from their ashen hue to a natural crimson. The patient commonly moves a limb or utters a cry, though not one which implies con-

* Laryngeal stertor must be carefully discriminated from "snoring." Patients with a thick pendulous uvula or enlarged tonsils or post-nasal adenoids start snoring a few seconds after the commencement of inbalation and this should be ignored. The true stertor caused by vibration of the arytœno-epiglottidean folds only comes on after at least a minute, and is more vocal in character.

sciousness; restless movements of the body often occur. The time which elapses between removal of the face-piece and the period of recovery to consciousness, varies somewhat; it is usually a minute, but may be as short as thirty seconds; or, on the other hand it may be prolonged to ninety seconds.

After Effects

Are as a rule conspicuous by their absence; hysterical women may laugh and cry and work themselves up to a pitch of excitement, which sympathetic friends attribute to "the gas"; persons exhausted by fasting and vigil or disease may become faint; epileptics occasionally have a fit during the exhibition of the gas or immediately afterwards. Vomiting is rare after nitrous oxide gas, although such a complication may occur with children, or if the anæsthetic be given immediately after a meal. Among a few persons of peculiar organisation, certain nervous symptoms have been known to follow. Thus, severe headache is sometimes occasioned, while cases are reported when hemiplegia, paresis, or hallucinations, are said to have ensued upon the administration of nitrous oxide gas.

Dangers Attending Nitrous Oxide Administration.

Among the graver complications may be noted syncope. While syncope seldom occurs during nitrous oxide narcosis, it is undoubtedly an ever present danger, especially among the neurotic and the feeble. It may occur before complete unconsciousness and is then

probably due in part to subjective sensations, such as fear of the impending operation, terror of the anæsthetic, or distress at the feeling of partial asphyxia which to some persons is very alarming. There are reported cases where syncope has only been observed after removal of the face-piece, while in others, all has apparently gone well until the operation had commenced, when the condition of the patient suddenly became alarming. Whether death from syncope has ever taken place under nitrous oxide is doubtful. In the few fatalities which have attended its use and been reported, incomplete anæsthesia has played an important part, while fright and shock have undoubtedly gone far in bringing about the untoward event.

Less severe forms of heart failure, however, such as faintness do sometimes supervene, and should be met by placing the patient prone on the ground, chafing the hands, applying smelling salts or aromatic vinegar to the nostrils and slapping the face and chest with towels wrung out in very cold water. All garments about the waist, chest and neck should be loosened if this has not been done as it should have been, before the gas was administered. The inhalation of a few whiffs of nitrite of amyl will, by emptying the blood into the dilated arterioles relieve the heart. It is sometimes advised to inject ether under the skin, but the utility of this measure is doubtful, nor is it likely to be called for in the class of cases above mentioned.

Breathing in some cases becomes very shallow and even stops altogether, but this need not cause alarm unless indeed it should cease for longer than five or six seconds. Then it is well to press up the ribs from below by standing in front of the patient, and grasping the chest with both hands placed about the lower half

of the bony thorax. This simple manœuvre will initiate spontaneous respirations and all will go well.

Among dangers occurring during nitrous oxide narcosis, must be mentioned those which arise rather from surgical interference than from the agent employed. Thus, when a prop is placed between the teeth, it should be guarded from slipping back into the wind-pipe by being tied to another prop hanging freely outside the mouth, and the props used should be made of some material not liable to crack or break off. The mouth should be cleared of artificial dentures, especially small plates. Accidents have arisen from teeth or portions of teeth being allowed to fall from the beaks of forceps back over the glottis, a deep inspiration then drawing the tooth into the trachea. The tooth forceps have, in recorded cases, broken and a fragment become lodged in the trachea.

The dangers of these casualties are: (1) immediate; from asphyxia due to laryngeal spasm excited by the foreign body becoming entangled in the larynx; and (2) secondary; from the working down of the foreign body into the bifurcation of the trachea and there setting up pulmonary trouble.

To deal with such cases:—Firstly, as to precautions. All instruments used for the mouth should be carefully examined for flaws, and all gags, props, etc., be secured by fishing gut or some strong cleanly material and attached outside the mouth.

In extracting teeth the forceps should after each extraction be wiped *twice*, as taught by Clover, before attacking another tooth. Fragments of teeth should never be left in the mouth, even with the object of gaining time; each fragment should be removed before any further proceeding.

Some operators employ a plated lattice mouth-spoon so held as to catch whole or broken portions of teeth. In practice, where an operator needs all the room he can get, this implement is not without its drawbacks. Should there be any fragments detached from the tooth or forceps, &c., which cannot be seen and picked out, it is the anæsthetist's duty at once to bend the head forwards and sweep the finger round the mouth so as to carry any foreign body forwards when it can be seized and removed, in this way it may sometimes be possible to dislodge a foreign body situate at the epiglottis. It should be remembered that the tongue must not be drawn forwards, as by so doing the larynx will be left exposed, the epiglottis being dragged from it, while the patient is thereby induced to take a deep inspiration which will probably cause the foreign body to enter the air-passage.

If the obstruction cannot be felt and there are signs of impending asphyxia, inversion may be attempted, and the patient instructed to expire very deeply, coughing with the act, while he inspires as shallowly as he is able. This manœuvre has succeeded in dislodging a tooth which had passed into the trachea.

Of course inversion is disadvantageous inasmuch as it may cause the foreign body to lodge in the larynx and so excite spasm. Failing these measures, if the patient be dyspnœic and death by asphyxia seems imminent, the trachea must be opened by the crico-tracheotomy operation (*see* Chap. X.).

Is nitrous oxide, dangerous to any particular class of persons ?

It sometimes happens that the anæsthetist is consulted as to the safety and expediency of giving nitrous oxide to (*a*) pregnant women; (*b*) persons whose vital-

ity is greatly lowered by age or disease; (*c*) the subjects of grave heart or lung diseases.

(*a*) **Pregnant women** provided they be not within a very short period of their accouchement are not prejudicially affected by laughing gas. The shock of a surgical operation, the extraction of a tooth or what not, is quite as likely to provoke premature delivery as giving the gas. The child also appears to be quite unaffected, as one would expect, since its oxygen tension is habitually low, and further because the elimination of nitrous oxide from the blood is very rapid. At the same time, especial care should be given in administering nitrous oxide in these cases, as the nervous system is peculiarly liable in these persons to receive stroug impressions and is easily thrown off its balance. Hysterical emotional outbursts if they occur will certainly be attributed to the inhalation, so that unless imperatively called for, operative measures should be deferred until after parturition.

Age, as such, offers no reason for declining to administer nitrous oxide, patients over ninety having taken it successfully. When great **vascular feebleness** exists there is more risk, as the greater tax imposed upon the heart by checking oxidation in the lungs and so impoverishing the tissues, may provoke syncope. However, with due care and watchfulness even the very feeblest can take nitrous oxide with impunity.

In extensive lung disease, especially in phthisis, when hæmorrhage has been known to have occurred, nitrous oxide must be given with caution, as there is a danger of occasioning fresh bleeding from the lungs. According to Mr. Braine narcosis deepens in phthisical patients after the withdrawal of the face-piece, and so special care is needed in the management of such cases.

Heart disease, save in so far as that the tendency to syncope is considerably increased, is no contra-indication for giving the gas. In all cases, it is necessary to weigh in one's mind which will be most likely to jeopardise the patient's welfare—the performance of an operation without an anæsthetic, or the giving of the anæsthetic. Broadly it may be stated, that if the patient can bear up against the operation, he will certainly survive the anæsthetic. (Snow).

Deaths from Nitrous Oxide Administration.

Several deaths have been imputed to the use of this agent, but it is doubtful whether any of the cases recorded were directly due to the physiological action of this substance. In some instances insufficient narcosis was maintained, and as a result the patient *felt the pain*, and syncope ensued. In others, either the entire gag or a portion of it slipped, and found its way into the patient's larynx, there to excite spasm and suffocation. In one instance, a person apparently whilst intoxicated, kept the face-piece applied and fixed it so that he became asphyxiated.

Paul Bert's Method of Administering Nitrous Oxide.

Paul Bert in the course of various experiments undertaken to ascertain the most safe and advantageous method of establishing anæsthesia by nitrous oxide, found that by administering it under pressure, he could prolong the administration practically for an indefinite period, while no injury to the subject resulted. Without referring in detail to Bert's experiments, which

are out of place in a practical manual, it may be well to epitomise his reasoning and give his results.

Nitrous oxide, when diluted with air or oxygen, is incapable of producing anæsthesia. When, however, it is given pure, the patient's tissues become de-oxidised from want of fresh income of oxygen. Further, nitrous oxide does not produce anæsthesia by dint of its replacing oxygen, nor is it rendered inoperative in the presence of oxygen, provided its tension in the blood be sufficiently high. It therefore appeared probable that were nitrous oxide to be administered under a pressure of two atmospheres (that is, so that fifty per cent. only of the atmosphere so inhaled was nitrous oxide, and the other fifty per cent. air, the nitrous oxide tension in the blood being then equal to one atmosphere, and at the same time sufficient oxygen entered the blood to maintain the due oxidation of the tissues), anæsthesia would result without any asphyxia. An apparatus was accordingly made by Dr. Fontaine (Fig. 5) which enabled the patient to be kept under an atmospheric pressure equal to 26 inches mercury, and this was successfully worked. Under this pressure nitrous oxide and oxygen being given in the proportion of 5 to 1, the tension of nitrous oxide was equivalent to one atmosphere.* Several operations lasting from five minutes to half an hour were successfully performed under anæsthesia produced by Bert's method.

In England the method has not been employed, as nitrous oxide and ether are practically as safe, and the large and expensive chamber and apparatus render its use, save in hospitals, almost impossible.

* For an excellent account of Paul Bert's method see the admirable work of M. Rottenstein, *Anethésie Chirurgicale*. M. Rottenstein assures me that even in France this method is now but little used.

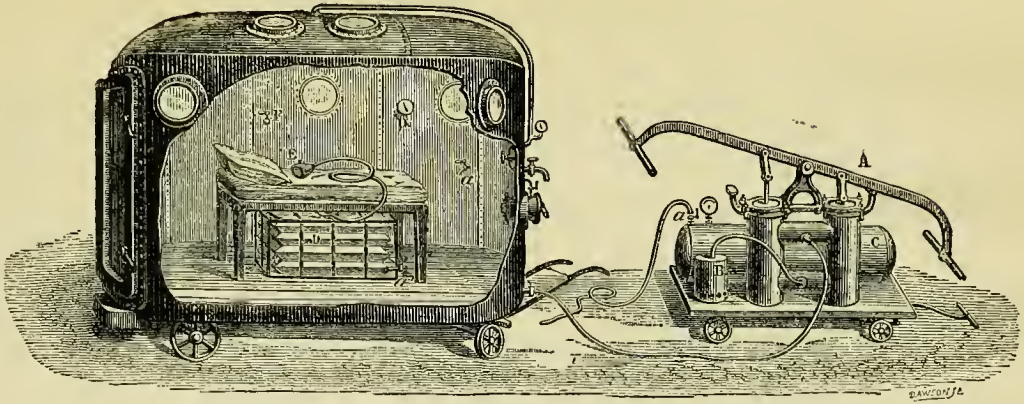

FIG. 5.—Fontaine's chamber and apparatus for forcing in air under pressure.

A. Double barrelled air pump.
B. Refrigerator through which the air passes.
C. Sheet iron container capable of holding 350 litres of the gaseous mixture under a pressure of 10 atmospheres.
D. Gas bag communicating with the face-piece E by a flexible tube.

CHAPTER IV.

Sulphuric Ether—Anæsthetic Ether.

Ether or Ethyl Ether $\overline{C_2H_5}^2O$, more accurately known as oxide of ethyl, was discovered in 1540 by Valerius Cordius.

Chemical and Physical Properties.—It is a clear, translucent highly volatile liquid, of a penetrating odour and a burning taste which is followed by a sensation of cold and numbness. It has a specific gravity of ·723 (at 54·5° F.) and boils at 95° F.; when pure it does not redden litmus. Ether does not mix with, but is slightly soluble in water, freely uniting with alcohol and chloroform. Applied to the skin, it gives a sensation of intense cold caused by the extreme rapidity of its evaporation.

Ether is highly inflammable; its vapour when mixed with air is liable to explode if brought in contact with flame; it is hence important to avoid the proximity of lighted gas jets, candles, etc., and to refrain from pouring ether out of one receptable to another in such surroundings. The substance is prepared by acting upon strong alcohol with sulphuric acid and heating the mixture to 140° to 150° C. (280°-300° F.). This compound undergoes double decomposition, ethyl sulphuric acid and water being first liberated, the ethyl sulphuric acid afterwards combining with a molecule of alcohol to form ethyl ether and sulphuric acid, thus:—

$$\begin{array}{ccccccc} C_2H_5O & + & HSO_4 & = & HO & + & HSO_4 \\ H & & H & & H & & C_2H_5 \end{array}$$

$$\begin{array}{ccccccc} HSO_4 & + & C_2H_5O & = & HSO_4 & + & C_2H_5O \\ C_2H_5 & & H & & H & & C_2H_5 \end{array}$$

and the sulphuric acid is ready to attack another molecule of alcohol. This, the so-called continuous etherisation process, is practically interminable, provided a fresh supply of alcohol be maintained. The ether so prepared is passed over fused chloride of calcium which removes the water and alcohol and is then rectified.

Ether, if kept in hot places and in an imperfectly stoppered bottle, is liable to undergo oxidation, acetic acid and other products form, and the reagent is thus rendered unfit for use. Ether, if pure, forms a clear mixture with oil of copaiba, but if it contains water or alcohol an emulsion will result.

The impurities to which ether is subject are :—

1. Water, detected by adding tannin, for when water is present the mixture becomes syrupy, while if absent the powdered tannin remains unchanged.

2. Alcohol, if present, gives a red stain with crystals of fuchsine; it also increases the specific gravity.

3. Acids, sulphuric and sulphurous, detected by the precipitate they give with barium chloride; acetic acid, which produces a deep-red colour upon the addition of an iron salt.

4. Fusel oil, may be detected by its leaving a greasy stain on paper.

General properties and uses.—Ether is an exhilarant and finally a narcotic; it is the safest known agent for the production of prolonged narcosis. It is employed alike for its power of producing local anæsthesia, which it does by provoking rapid abstraction of heat so as to numb the cutaneous endings of the sensory nerves, and also on account of its capacity for inducing complete insensibility to pain (general anæsthesia) through its action upon the cerebro-spinal centres.

Ether for general purposes is the best and safest

anæsthetic; it is superior to nitrous oxide, because it may be inhaled for hours without endangering life; it is less dangerous than chloroform because its undiluted vapour is practically safe, whereas, chloroform unless kept below four per cent. of the air breathed, seriously imperils life.

There are, however, CASES IN WHICH ETHER SHOULD NOT BE USED.

(*a*) In protracted operations about the mouth, jaws, nose, or pharynx, which necessitate the mouth and nose being uncovered. Since consciousness rapidly returns when the supply of ether is discontinued, there is not time for prolonged surgical procedure.

(*b*) All operations needing the employment of the actual cautery, or lighted candles, lamps, &c., in the vicinity of the mouth, ether being highly inflammable and when mixed with air detonating, so that the incautious bringing of the apparatus near a light may lead to grave consequences.

(*c*) Persons who are suffering from bronchitis, and those liable to that complaint; the emphysematous (if the condition be very pronounced), and as a rule asthmatics bear ether badly, since it excites cough and may clog the bronchial tubes with a quantity of excessive secretion.

(*d*) In renal disease, when extensive, ether is said to induce suppression of urine, so that if given at all in these cases it should be with the utmost caution.

(*e*) The vascular excitement to which ether gives rise contra-indicates its use for persons, whose arteries are presumably brittle, or in whom circulatory perturbation is likely to be harmful. It is obvious that when cerebral hæmorrhage from rupture of an artery has once occurred, ether might, by increasing arterial tension, induce a repetition of so dangerous an accident.

(*f*) In infants and very young children ether sometimes produces great pulmonary trouble from its irritating effects upon the delicate mucous membrane of the respiratory tract. However, with the exception of the conditions considered under (*e*) no hard and fast rule negatives the use of ether. Further, other anæsthetics may be contra-indicated and then ether may be advisable even in cases grouped under *a*, *c* and *d*.

(*g*) As ether always provokes rapid breathing and not infrequently coughing, it should not be used when these are prejudicial to the patient, or to the success of the operation.

(*h*) The presence of brain tumours, intestinal obstruction, and cancerous tumours is by some considered contra-indicatory of ether. (Wood).

Physiological Action of Ether.

Ether when first inhaled, induces a burning sensation in the mouth and pharynx and a feeling of impending suffocation. It appears to act in two ways; indirectly through the nerve centres as a powerful deliriant and anæsthetic, and directly upon the endings of the nerves supplying the pharynx and respiratory tract. Thus it increases the flow of saliva, and causes considerable discharge of watery secretion from the bronchial mucous membrane. Its extreme volatility makes it exert a marked cooling action upon skin or mucous membranes, when allowed to come into contact with them; and further the vapour if injudiciously employed, may excite a highly prejudicial chilling effect upon the bronchial lining membrane, resulting in catarrh or even bronchitis.

In the rhythm of respiration, ether brings about

marked changes. If the full strength of ether vapour be allowed to impinge upon the glottis, the muscle is thrown into spasm and the rima becomes temporarily closed. Indeed ether has been shown by Horsley and Semon to exert a marked local action upon the laryngeal muscles. These observers have further proved that the action differs according to the degree of anæsthesia induced, in other words, according to the dose of ether given. Slight ether narcosis produced adduction while deep etherisation resulted in abduction of the vocal chords, and these results obtained with strong or weak currents and when the recurrent laryngeal nerve was divided or left intact.

At first the respirations are hurried and deep, subsequently they become slower and more shallow and would eventually, were ether pushed to such a dangerous extent, altogether cease. This slowing and final cessation appear to be due to ultimate poisoning of the respiratory centre in the medulla.

The heart's action is at first excited and increased in force; later this subsides, the heart quiets down, or even grows somewhat weaker, though such weakening is always trifling. The blood pressure is increased until very deep narcosis is present, when a slight fall of pressure occurs. A peripheral vascular dilatation reveals itself in flushing and rubescence of the skin, together with sweating and a roseolous rash. According to Sansom, in the earlier stage of etherisation, capillary constriction takes place. Under ether the *muscles* at first become rigid and firmly extended, but later these conditions give place to extreme flaccidity; in some persons the muscles maintain their rigidity much longer than in others, while there is a difference in the time which muscles in various regions take to relax. Ringer, experimenting on muscle,

found, that in frogs, the vitality of involuntary muscle persisted far longer in the case of ether than in that of chloroform. Peristalsis although lessened is not abrogated, even when death is induced by ether.

The *nervous system* during etherisation becomes profoundly affected. The *cerebrum* first succumbs. Excitement and hallucinations appear, the patient believing that he is engaged in mortal combat or in some habitual pursuit. He may struggle and cry out; soon, however, his speech becomes thick and inarticulate, his struggles cease and his mind no longer controls his movements. The *sensory nerves* of the spinal cord then fail to convey impressions from without, although stimulation of the motor nerves induce movements. Later, the *motor nerves* also cease to respond, save to powerful electrical excitation (Longet). The *medulla* becomes next affected, at first sensory impressions fail to reach it, finally its motor centres become paralysed, respiration is arrested, and the heart ceases to beat. It appears that these results are due to the direct action of ether, conveyed by the blood to the nervous centres, since they occur even after section of the pneumogastric nerves, and when the anæsthetic is injected directly into the veins. Hence it would seem that ether directly affecting the centres, acts first as a stimulant and later as a depressant. When artificial respiration is maintained the heart will continue to beat for a prolonged period, and this even in spite of very large quantities of ether. The bodily temperature is reduced under ether; Kappeler fixes a minimum at ·3° C., and a maximum at 1·5° C. (·5°—2·7° F.). It increases the secretions with perhaps the exception of that of the kidneys. Elimination takes place rapidly and is mainly effected by the lungs.

Methods of Administering Ether.

Ether may be given alone or in combination with nitrous oxide gas, the latter method possessing the following advantages:—The patient is spared the disagreeable smell and taste of ether. He becomes narcotised more rapidly and without struggling or excitement.

The main indications for the successful administration of this anæsthetic are:—That the air inhaled is

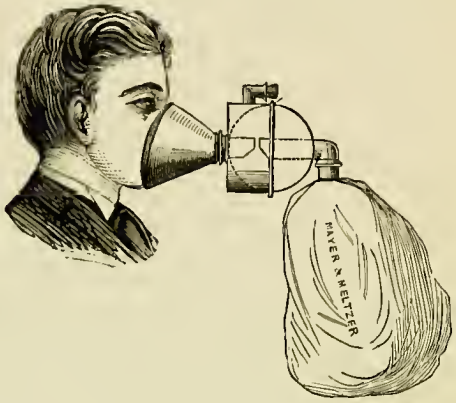

Fig. 6.—Clover's Portable Ether Inhaler.

saturated with ether vapour, unsaturated air being excluded; that the vapour shall not escape into the room and impregnate the air breathed by the operators and bystanders; that during the first few respirations the patient shall inhale a vapour so dilute as not to irritate his larynx. Ether cannot be given properly from a folded towel.

Clover's inhalers fulfil the above requirements best, and they also use less ether.

The figure represents Clover's Portable Ether Apparatus.

The face-piece is edged with an air cushion. The ether vessel and water chamber which surrounds it and maintains it at the desired temperature for evaporation, rotate upon the mount of the face-piece. When the instrument is first applied, the stopper should be opposite the patient's forehead, and the indicator which travels round the lower end of the water chamber pointing to the figure 0. The bag should not be placed in position until the patient has taken two or three inspirations, it must then be inflated by blowing air into it and be fitted to the upper end of the water chamber as shown in the figure. As the ether vessel is turned round the indicator travelling from 0 to 1, 2, 3, and F successively, the air has to traverse the ether vessel before reaching the bag, and so the patient gets gradually a more and more highly saturated ether atmosphere. Two ounces of ether are poured into the projecting arm before the operation, and these usually suffice for the case. The opening is so arranged as to prevent an excessive quantity being used and to guard against the possibility of a few drops escaping through the inner openings.

The ether vessel and surrounding water chamber are so arranged, that although the vapour freely escapes, no fluid overflows in whatever position the inhaler may be held. The water chamber is centred by a shaft which communicates with the interior of the ether receptacle, and the vapour escapes into this shaft. From below a hollow metal cylinder fitting to the face-piece, and above shaped like a clarionet mouth-piece,

enters the shaft and closes it, being able at the same time to rotate with the face-piece. To this is fixed the long metal indicator turned at right angles at its extremity. From above a similar shaped piece of metal is fixed, so that the two "clarionet" pieces are adjacent, the lower one capable of rotation, the upper one fixed. Finally the shaft is completely closed above by the air bag, which is attached to a metal cylinder, closing but freely movable in the shaft. Ether can only reach the patient, when the two "clarionet" pieces wholly or partially coincide. When the lower piece moves, the indicator travels with it, and should it point to 0, the ether way is blocked, and then the patient breathes simply air through the shaft in and out of the bag. As soon as the indicator is moved from 0, the "clarionet" pieces cease to shut off ether, and the air enters the chamber and becomes impregnated with its vapour. When F is reached, the patient is inhaling ether vapour diluted only by the amount of air exhaled from his lungs. The following is the method of using this inhaler:—The appropriate sized face-piece being selected and two ounces of ether placed in the receiver, the air-bag is removed and the indicator turned to 0. The patient is then directed to inspire deeply, and the face-piece applied firmly but gently. Uniform pressure is well borne, while hard pressure if unequally distributed, will not be tolerated. When the patient has taken two or three deep breaths, the air-bag is filled by the administrator blowing in air, and is placed into an aperture at the top of the dome, so that the patient now breathes in and out of this bag. The indicator is now moved to 1 so that the patient is breathing one-fourth ether and three-fourths air. A few breaths of such a dilution of ether will accustom the larynx

to the irritating vapour, and so obviate coughing, spasm, and the wretched feeling of suffocation which ensues upon presenting a strong ether atmosphere to the patient at the commencement of an inhalation. This tolerance achieved, the indicator is pushed to 2, and the patient then inhales half ether and half air. If this strength of vapour do not distress him, the indicator can be, after a few seconds, carried to 3 (one-fourth part air, three parts ether) and then to F (all ether). The patient will in from ninety seconds to two minutes and a half, be completely unconscious and ready for operation. Some persons require more ether to put them off, and those who persistently resist taking the anæsthetic by holding their breath or by taking the shallowest breaths consistent with life, will delay the onset of unconsciousness much longer. These persons also, since they voluntarily semi-asphyxiate themselves by repressing respiratory movements, suffer great additional discomfort from the feeling of suffocation they induce.

As soon as complete anæsthesia is thoroughly established, the indicator may be brought back to 2, and there kept until the operation is over. It may be necessary in warm weather, and in the case of prolonged operations to renew ether in the receiver. This is easily done by removing the inhaler from the patient's face, loosening the cork, and pouring in a further supply.

The patient will, during a prolonged operation, require the inhaler taken off his face every sixth breath or so, in order that he may take a few inspirations of air. The necessity for this will be readily recognised by the degree of cyanosis apparent in the face, and by the character of the respirations and the pulse. It should be carefully borne in mind, that the amount of an anæsthetic

required to produce narcosis is much greater than is needed to maintain that condition. Also the degree of narcosis, must be varied in correspondence with the region of the body, upon which operative measures are being pursued.

Clover's larger ether inhaler is figured on p. 30. It is used mainly if not exclusively for giving nitrous oxide

FIG. 7.—Ormsby's Ether Inhaler.

and ether in combination. The method of using it without nitrous oxide is simple. The air bag is fully inflated by the administrator, who then moves the indicator off the dial plate and turns the ether tap. The indicator is next turned to G when air only will be taken. As soon as the indicator passes towards E, ether begins to be received; the same principles and

cautions guide the further proceedings with this, as were employed for the other inhaler.

One of the commonest inhalers in use is that called after its designer, Dr. Ormsby, of Dublin. It consists of a leather face-piece with cushioned rim, provided with a valve, which can be opened at the pleasure of the administrator; at the top of the face-piece is a cone-shaped wire cage, covered externally with leather, and leading into a soft leather bag covered by a loose net which prevents its undue expansion. In the wire cage, a sponge is placed and upon this an ounce of ether is poured. The apparatus is applied to the patient's face and he strives to take a full breath. Even when the valve is kept widely open the sense of suffocation is so great (the rush of ether vapour producing more or less spasm), that the patient struggles fiercely to escape what appears like impending asphyxia.

Should it be necessary to add fresh anæsthetic during the operation, it is done by pouring ether down a tube which enters the centre of the sponge.

Ormsby's inhaler is open to several objections; *e.g.*, it produces great discomfort by allowing undiluted ether vapour to impinge upon the larynx; the sponge is very liable to freeze hard, and so no evaporation of ether takes place; it occasions great struggling; it is wasteful of the ether.

Other Inhalers.

The cone.—This is a contrivance largely used in America. The ether is poured into the cone, upon a sponge, and renewed from time to time by inverting it and pouring in a fresh supply.

The cone of which Ormsby's inhaler is but a modification, is open to the same objections for a similar reason.

Many other forms of apparatus have been invented but as they possess no peculiar merits and are seldom used in this country, I must omit further mention of them.

FIG. 8.—Rundle's mask and flannel cap in cone.

The effects of ether inhalation will vary considerably according as the patient is narcotised rapidly or slowly. Slow etherisation possesses no advantages and is indeed positively harmful by prolonging the stage of delirious excitement.

The patient being placed in the prone position and his clothing ascertained to be loose, his mouth is examined for artificial teeth or an obturator, and if such exist they are to be taken out and ether administered by one of the above apparatus.

When the patient first breathes ether vapour, he catches his breath; may cough, and resists the ingress of the vapour. This will be in proportion to the strength of vapour used. A few inspirations will render him dazed, the face will flush, the eyes grow suffused, and the breathing become rapid. The pulse in this stage is large,

softer than natural, and accelerated. Although stupefied the patient can still perform certain voluntary acts, *e.g.*, putting out the tongue if loudly ordered to do so. The feeling of suffocation which was at first experienced now gives place to one of exhilaration, the dyspnœa disappears, and the respirations are full and deep. Formication and tingling are felt in the hands and feet. The pupils usually contract in this stage. The exhilaration, however, soon passes into a condition of delirious excitement. Bert denied that true excitement occurs, believing that progressive loss of muscular power supervenes, while the disorderly movements commonly put down to excitement of delirium are to be explained as *une sorte d'anarchie cérébrale*, the guiding centres being in abeyance. In whatever way we regard these movements, they certainly appear to be the result of temporary delusions. Thus, military men will, in this stage of etherisation, shout words of command; while those inclined to pugilism will attempt to box with the bystanders. The respirations and heart's actions are considerably accelerated; the skin grows moist, the face dusky. Soon a period of quiet follows, and it should be the aim of skilled etherisation to curtail as much as possible this condition of excitement. In the succeeding quietude the limbs stiffen, the muscles grow strongly contracted and firmly set, the whole body becoming rigid. Breathing is hampered by the rigidity of the thoracic muscles and needs watching at this time. Should respirations stop it will be necessary to firmly press two or three times upon the chest, and so force in the air. The pupils dilate and the skin becomes bedewed with perspiration, while a roseolous rash appears in patches about the neck and chest. These patches coalesce. The pulse resumes its normal

rate, and although soft, yet remains regular and somewhat more forcible than before the anæsthetic. Now ensues the stage of muscular relaxation. The patient lies absolutely insensible to all external impressions with his muscles perfectly flaccid. The breathing slows although it keeps quicker than normal, and is much more shallow. At this time anæsthesia may be taken as complete, and operative measures may proceed.

Dangers and Accidents.

The chief troubles which occur during ether narcosis are connected with **respiration.** In the first place the breathing may be stopped through obstruction in the larynx, the rima glottidis becoming closed and no air entering the lungs. In some cases the rigidity of the muscles may cause impediment to air entry by provoking tight closure of the teeth. Inspiration through the nose is greatly hindered or prevented by the nostrils being sucked in with inspiration. In this way little air can enter the chest and the patient grows cyanotic. If the teeth be forcibly opened by a screw gag, air will enter freely and the cyanosis pass off. The movements of respiration do not cease in the condition of laryngeal spasm, whether partial or complete.

Treatment.—The head must be thrown back and the tongue drawn forward; by this means respiration may be induced to start, but failing this, tracheotomy must be performed.

A more troublesome, although fortunately a rare complication occurs, when the thorax becomes fixed by the rigidity of its covering muscles. The treatment

here is to maintain the air way open, and to attempt to overcome spasm by artificial respiration.

But if ether be incautiously pushed for a prolonged period, without allowing the patient to renew the air in his lungs from time to time, the respirations may stop altogether, although the muscles will be quite flaccid. This condition would appear to ensue upon the overloading of the blood with ether, leading to poisoning of the respiratory centre. The treatment is the immediate performance of artificial respiration. If this be properly done the blood soon becomes duly oxygenated, and the nerve-centres being once more supplied with depurated blood, recover their control over the respiratory mechanism, and so natural respiration will ensue.

Rarely, the **heart** may give trouble. In a few recorded cases fatal syncope has occurred at the commencement of ether inhalation, but whether such casualties can be justly imputed solely to ether influence, is I think doubtful. Less important inconveniences of ether inhalation are the great secretion from the mouth and respiratory tract; this although interfering with respiration is seldom of any great importance. It must be remembered, however, that in infants and weakly persons it may prove a grave after complication, giving rise to blocking of the tubes and water-logging of the lungs.

Coughing occurs in many persons, especially if ether vapour be given in too concentrated a form; but it is a mistake to remove the inhaler for this in all cases, as frequently while a dry cough occurs in the earlier stages of etherisation, it is suppressed by pushing the anæsthetic.

Vomiting during the operation is nearly always due to the giving of too little ether, and follows upon the

partial resumption of consciousness. The patient will be observed to inspire irregularly with shallow breaths, followed now and again by yawning inspirations. This will be succeeded by efforts at swallowing, rapid and chiefly abdominal inspirations ensue, and the patient retches and vomits. Conjunctival reflex returns just before the sickness.

Two indications are now paramount, to get rid of the vomited matter and to avoid any of it being drawn into the larynx by the deep inspiration which always follows the act of vomiting; secondly to prevent complete return to consciousness. To obviate these the patient's head should be turned to one side without being raised and all vomit removed with the finger; then the inhaler should be rapidly re-applied, and if further vomiting occur recourse must be had to similar manœuvres. But a judicious pushing of the anæsthetic at the first signs of the onset of vomiting will often, if not always, prevent the occurrence of sickness. In carrying out this plan great care must be taken, lest if it fail and vomiting occur, the ejected matter should enter the windpipe. If vomit be drawn into the trachea and cannot be coughed up, it may be necessary to open that tube and to take measures for the removal of the foreign bodies from the air passages.

After Effects of Ether.

Nausea and vomiting in some cases prove troublesome and very intractable. They usually occur in persons whose general health has been impaired before receiving the anæsthetic. All food and stimulants must be withheld for three or four hours after ether, and the

patient be encouraged to take tea-spoonfuls of *hot water;* tepid water provokes more vomiting, hot water checks it. The use of metal spoons in so administering the water should be avoided that the lips and tongue may not be blistered. In some cases iced soda water in sips will check vomiting while iced black coffee with a bromide is often efficacious (gr. x. to a small cupful). Absolute quiet with an enforcement of the supine position must be observed, while the patient is placed in an airy room with windows opened, and well covered with blankets or rugs. In lesser degrees of sickness, sucking pieces of ice is useful; but the loading of the stomach with ice cold water is a measure often followed by great sickness and discomfort.

Should vomiting continue and there be accompanying collapse, iced dry champagne may be given in tea-spoonful doses every quarter of an hour until improvement occurs.

Some persons suffer from great nausea without much sickness. Small doses of tincture of nux vomica will do good in these cases, one minim in a tea-spoonful of water, by preference hot—may be taken every ten minutes for an hour. This will usually check the nausea, and failing it, Dr. Ringer's suggestion of drop doses of vin. ipecac. may be tried. Dilute hydrocyanic acid in minim doses is also useful.

Hiccough, which is sometimes very severe after ether, may be cured by mustard (℥ j. infused and added to ℥ iv. of boiling water) taken in sips. Less unpleasant remedies are cajeput, musk, chloral, and morphine (administered hypodermically). A small cup of strong green tea taken hot and without sugar or milk will often check hiccough.

CHAPTER V.

Chloroform.

Chloroform ($CHCl_3$) was discovered by Soubeiran in 1831, and termed by him bichloride of ether. Liebig discovered it independently in 1832, and classed it as a chloride of carbon. It was not, however, until 1834 that the true composition of chloroform was understood, and its properties enunciated by Dumas. As is well-known, its employment as an anæsthetic was due to the advocacy of Sir James Y. Simpson, in 1847, after its having been introduced to his notice by Mr. Waldie, of Liverpool.

Chemical and Physical Properties.—It is a limpid heavy liquid with a specific gravity of 1·497 at 62·5° F. (17° C.) (Regnault); vapour density 4·199 (Dumas). It has an agreeable ethereal smell and sweet taste. Its vapour is not easily inflammable, but if ignited burns with a green flame. It is very volatile, but although mixing freely with air, pure chloroform vapour can only exist at a temperature of 140° F. When exposed for some time to light, chloroform splits up into chlorine and hydrochloric acid. It boils at about 142° F. (61° C.) (Regnault). To test-paper, chloroform should be absolutely neutral. Soluble only to the extent of one-half per cent. in water it freely mixes with ether and alcohol.

Chloroform is prepared by the action of rectified spirit on chlorinated lime in the presence of slaked lime. After distillation the impure product is refined with water which removes the alcohol, chlorine, etc.; oily

matters are disposed of by washing with sulphuric acid, while the remaining matter is eliminated by distillation over dry chloride of lime and slaked lime.

Chloroform is liable to contain certain impurities :—

Alcohol.—This must be present in a small quantity in order to prevent decomposition of the chloroform. The impurity is detected firstly by the specific gravity which if below 1·48 points to adulteration, probably by alcohol.

Tests.—1. A few drops of the doubtful chloroform are added to a solution of white of egg, and if alcohol be present to the extent of 2 or 3 per cent. (Letheby) the albumen coagulates.

2. A mixture of equal parts chloroform and almond oil becomes turbid if alcohol be present.

3. The suspected chloroform is dropped into distilled water ; if containing alcohol the otherwise transparent globules look as if surrounded by a milky halo of opalescence (Mialhe).

4. Chloroform if contaminated with alcohol gives a green colour with chromic acid.

Ether may be found in some samples of chloroform, its presence being revealed by its odour and by globules taking a dull-red colour with iodine, thus contrasting with the violet shade which pure chloroform gives (Berchon).

Crystallised nitro-sodic sulphide of iron is dissolved if alcohol or ether be present in chloroform.

Methyl Compounds.—These give rise to nausea, headache, lassitude ; they are detected by adding strong sulphuric acid to the chloroform, which becomes black in their presence.

Hydrochloric acid and *chlorine* are liable to be developed if chloroform be exposed to light and air. The first gives an acid reaction ; the last has a characteristic

odour and bleaches. Suspected chloroform may be shaken with distilled water and this tested with nitrate of silver for chlorides. The presence of free acid is also shown by adding sodium, which in contact with the acid produces an evolution of gas.

Physiological Action of Chloroform.

Chloroform behaves somewhat differently according as it is applied—(1) to the skin or an abraded surface; (2) to the mucous membrane of the alimentary tract; (3) to the mucous membrane of the respiratory tract.

Upon the skin and abraded surfaces chloroform benumbs and acts as a strong irritant. If the contact be prolonged and if evaporation bo prevented, vesication will ensue. It is therefore most important to guard against these effects during the administration of chloroform by protecting the face by smearing it with vaseline.

Upon the mucous membrane of the alimentary tract.—When swallowed, chloroform produces a sensation of warmth and has a sweet taste. Anæsthesia follows the swallowing of a considerable quantity, but other and dangerous symptoms of irritant poisoning are provoked by the introduction of this drug into the stomach. (See *Medico-legal Aspects of Anæsthetics*, Chap. XII.). Acute gastritis and death from collapse have in some cases followed.

Chloroform when inhaled produces very different effects according as it is given pure or diluted with air. Given to animals in concentrated vapour (air saturated), artificial respiration being performed, chloroform soon causes the right ventricle to distend and become en-

gorged, the heart ceasing to beat. When respiration is not maintained by artificial means, it ceases either before the heart stops or simultaneously. I have found that the hearts of animals killed by a lethal dose of chloroform show fibrillary irritability for some time after the heart-muscle as a whole is incapable of contracting in response to electrical or mechanical excitation.

Various parts of the nervous system appear to become affected in the same order as obtains in the case of ether, that is to say the cerebral centres are influenced before the sensory fibres of the cord, and these before the motor fibres, while last of all the medulla becomes paralysed. It therefore appears that chloroform may kill in two ways: firstly by interfering with the heart's action and so inducing syncope, and secondly by paralysing the vital centres in the medulla. In the former case death takes place early in the narcosis, but in the latter only when the blood is saturated to a certain (at present unknown) point.

Chloroform seems to have a selective action upon the nervous system, analysis of the tissues of persons who have been killed by chloroform showing that the brain and cord contain proportionately more of it than other tissues (Lallemand, Perrin and Duroy). What is the nature of the action upon the nerve centres we are unable to say, but evidence points to the probability that it is exerted upon the tissues themselves. Harley and others have asserted that chloroform produces destructive changes in the red blood corpuscles, and they explain the occasional jaundice following chloroformisation as arising therefrom. Others have believed, but upon insufficient evidence, that chloroform exerts its influence by changes which it effects in the process of oxidation. It has been shown that chloroform exercises a direct influence upon

the muscular tissues of the heart, although voluntary muscle is but slightly affected. Chloroform although possibly in part split up (Zeller), certainly in bulk remains unaltered, and is eliminated unchanged in the urine, the breath, and the milk. Its use produces a marked lowering of blood pressure, although this may be preceded by a very transient rise. The fall is due in part to paralysis of the vaso-motor system as has been shown by Bowditch and Minot, and in part to the diminished force of the heart's action, itself a result of the chloroform. Large doses of chloroform cause the heart to stop at once and it becomes absolutely inexcitable. It is doubtful whether arrest of the heart be due to direct action of the chloroform upon its substance, or whether it be reflex inhibition through irritation of the nerve endings of the pneumogastrics in the lungs. We know from experiment that chloroform is able to stop the heart when applied directly to its substance, and we know further that it actually kills the heart muscle and destroys its contractility.

With regard to the reflex theory above mentioned it must be admitted that we are at present without any actual proofs of its truth. Chloroform, as has been previously pointed out, acts upon the medullary centres; presumably each individual can take a certain quantity varying according as he is capable of eliminating the drug, and when this quantity is exceeded, the respiratory centre becomes paralysed, and respiration ceases while the heart-beat persists for a few seconds longer. The further action of chloroform upon the body is slight; it produces some increase in salivary secretion, and in small quantity excites vomiting. In a certain proportion of persons it provokes icterus. Astigmatism has been observed as

following the narcotism of chloroform. Albuminuria and glycosuria are also recorded as being induced by this agent.

On the Human Subject.

In describing in detail the action exerted by chloroform upon the human subject, it is convenient to divide the period of narcosis into five stages.

In the first stage—from commencement of inhalation to impairment of consciousness—fulness of the head, ringing, buzzing in the ear, palpitation of the heart are sometimes felt; there is also some diminution of common sensation.

In the second stage the mental powers are impaired although not suspended. The patient remains passive as if sleeping or occasionally makes a voluntary movement. Sometimes laughing, singing, talking are indulged in during this stage. Snow believed that dreaming occurs at this time and then only. Towards the close the patient becomes restive, he attempts to remove the face-piece or towel for he is conscious of being inconvenienced by the vapour but not of the necessity for remaining passive. Common sensation is much blunted so that patients submit without expostulation to painful manipulation. This degree of narcotism is sufficient for obstetric practice, and the after stage of prolonged operations. As a rule, struggles or expressions of pain which show themselves at the time are not subsequently remembered.

In the third stage all voluntary movements are lost. The conjunctival vessels become full, the muscles rigid, and struggles, even epileptiform convulsions, may super-

vene. As the stage advances the muscles relax. Inarticulate jabbering and mouthing occur. Although really insensitive to pain, the patient may flinch or even cry out. Later in this stage all reflex acts are abolished, the conjunctival and nasal receding last. The patella jerk also persists late, while under deep anæsthesia the ankle-joint phenomenon appears.

In the fourth stage breathing is stertorous, the pupils dilated and the muscles completely relaxed and flaccid. In this stage the patient is profoundly unconscious and is drifting into danger. Such deep narcosis is seldom needed save for the reduction of old-standing dislocations, etc.

The fifth stage is the interval which, following the fourth degree of narcosis, intervenes between the respiratory embarrassment and total cessation of breathing. Even after dyspnœa has passed into apnœa the heart continues to beat for a brief while. This stage marks the period when chloroform tension in the blood is great enough to paralyse the respiratory centres in the medulla oblongata.

Chloroform enters the blood until an equilibrium is established between the tensions of chloroform in the residual air in the lungs and that in the serum. So long as the tension in the air is maintained above or equal to that in the blood, no chloroform can leave the serum through the agency of the pulmonary mucous membrane. Snow demonstrated this theoretical statement by actual experiment substantiating the truth of the *à priori* statement, and so he arrived at the following law:—"As the proportion of vapour in the air breathed is to the proportion that the air, or the space occupied by it, would contain if saturated at the temperature of the blood, so is the proportion of

vapour absorbed into the blood to the proportion the blood would dissolve."

The amount of vapour which can be taken up (held in solution) by the air of the atmosphere varies with the elastic tension of the chloroform vapour at different temperatures. Thus at 40° F. a small quantity of chloroform would evaporate into air; at 130° F. so much would volatilise as to give rise to an almost pure chloroform vapour. In the following table taken from Snow's "Anæsthetics" the amount of chloroform in vapour is shown in 100 cubic inches of saturated mixture of air and chloroform at different temperatures.

Degrees F.	Air per cent.	Vapour per cent.
40	94	6
45	93	7
50	92	8
55	90	10
60	88	12
65	85	15
70	81	19
75	78	22
80	74	26
85	70	30
90	65	35

One grain of chloroform in one hundred cubic inches of air produces the second degree of narcosis but never carries chloroformisation further. This corresponds to a proportion of 1 part by measure of chloroform in 16,285 parts blood, or 0·0000614 the proportion by weight. Two grains in each hundred cubic inches of air, or $\frac{1}{28}$ saturation (unity being saturation), produces the fourth stage of narcosis or 0·0001228 the proportion by weight.

Any proportion above two grains in the hundred causes interference with respiration, three grains in the hundred seems about the ratio which renders respiration impossible. Three grains represent 2·3 cubic inches vapour and as air at 100° F. can take up 43·3 per cent. of its volume, the blood must contain from $\frac{1}{18}$ to $\frac{1}{19}$ of the proportion it is capable of absorbing when the respiratory centres are poisoned.

Snow found further that calculating the weight of the blood as thirty pounds, twelve minims of chloroform in the circulation produces narcosis of the second degree; eighteen minims the third degree (surgical anæsthesia); twenty-four deep narcosis (fourth stage), and thirty-six should paralyse the medullary centres. In practice more is needed because a certain proportion evaporates from the tracheal and bronchial surfaces and is carried out in expiration. If twelve minims be evaporated into a bladder and inhaled to and fro, no more air being allowed than can be blown from the lungs, narcosis of the second degree actually results. Now taking thirty-six minims as a lethal dose, the following considerations, upon which Snow strongly insisted, explain how easily this quantity may enter the circulation if the administrator be not perpetually upon his guard against over dosage; 18 minims represents the amount absorbed to produce surgical narcosis, this amount might be absorbed by the use of 36 minims, the remaining 18 minims being exhaled as above mentioned. These 36 minims represent 37·5 cubic inches of vapour which at 60° F. would require 257 cubic inches of air. The 300 cubic inches thus formed would be inspired in twelve respiratory acts (25 cubic inches being the amount of tidal air). Now if a vapour of this strength were continuously inhaled, the residual and complemental air

would become saturated, and as about 250 cubic inches represents the air in the lungs, this amount would at 60° F. contain the vapour of 30 minims. Assuming only half this quantity to be absorbed, that is 15 minims, we should then have 18 + 15 or 33 minims in the blood, an amount almost if not quite enough to paralyse the respiratory centre. These points being held in remembrance will explain many cases of chloroform death, ascribed to "idiosyncrasy" or the "fatty heart" which stands inexpert chloroformists in such good stead. Death from chloroform does not, however, always result from respiratory paralysis.

Working in the same lines as Snow, Paul Bert examined the action upon animals of small percentages of chloroform vapour in air. He asserted that atmospheres containing chloroform below a certain per cent. failed to induce anæsthesia; below a higher percentage (*zone maniable*) produced anæsthesia without danger to life, even when a vapour of this strength were persisted in for an indefinite period, while above this higher percentage death always occurred. The lethal percentage he found to be double the smallest quantity necessary to induce anæsthesia. Lister who repeated Bert's experiments, found no true *zone maniable* ("workable zone") to exist. Indeed, the French observer appears to have overlooked the important fact that chloroform not only kills by paralysis of the heart, but by failure of respiration. Richardson whose views seem to differ from those who adhere to the percentage theory, suggests that death from chloroform is, when it occurs in the latter stage, due to the cumulative action of the drug.

The Administration of Chloroform.

Various as are the methods in vogue in this and other countries, they may with propriety be grouped under two headings. 1. When an inhaler is employed. 2. When the open method is followed.

Among the multitude of inhalers which have been devised, we may notice **Clover's chloroform apparatus,** which consists of a large bag capable of containing a given volume of air ; into this the vapour of a given quantity of chloroform is allowed to enter, and the mixture is so arranged that the tension of chloroform vapour in the air is maintained below 4·5 per cent. The bag is constructed large enough to hold sufficient for several patients. It is connected at one end by a flexible tube with a face-piece, and at the other, with a bellows worked by the foot. To the bellows is attached a small metal receiver, into which a known quantity of chloroform is pumped by a graduated syringe inserted into the lid. Forty minims of the narcotic are supplied with every thousand cubic inches of air pumped in, and as these represent forty-five cubic inches of vapour, the percentage of chloroform never exceeds about 4½ per cent.

Chloroform kills by concentration of its vapour, hence our aim in its administration is to maintain the amount of chloroform in the respired atmosphere below the dangerous percentage (five per cent.). A percentage of five is very distinctly lethal. But it has also to be borne in mind that chloroform is a cumulative drug, that it is not changed during its passage through the body, and that its elimination depends upon the healthy work-

ing state of the emunctories, more especially the lungs and kidneys. Hence the percentage of chloroform with which we start will be unnecessarily high for the maintenance of anæsthesia when narcotism is once effected, and any method employed which hinders free expiration or hampers chest movements, is most prejudicial to the safety of a patient. Yet again, persons vary so largely in their resistive power towards chloroform, that it is impossible to feel sure a percentage which would be necessary in one case would be adequate in another. But while we are dealing with an agent which is admittedly dangerous in high perceutages, one is apt to rush into another extreme, and allow the percentage to fall so low that complete anæsthesia is not maintained. In this case the patient's safety is as much in jeopardy as when he is inhaling too concentrated a vapour. It will readily be seen that even the best inhaler may involve many risks as, with perhaps the exception of Clover's, none can absolutely maintain the desired percentage.

Snow's inhaler.—This consists of a metallic cyliudrical vessel, in which are fastened four stout wires descending nearly to the bottom, which fix two coils of blotting paper, these go quite to the bottom. The coils are cut into four, and are thus allowed free circulation of air, which enters through perforations iu the upper part of the cylinder. Outside this part of the apparatus is another cylinder which is filled with cold water. A glass tube communicates with the interior, the tube passes to the outside and so enables the admiuistrator to see when fresh chloroform will be required. The face-piece is fitted with an expiratory and an inspiratory valve, which last communicates with a ¾-inch tube fixed to the inhaler. The air enters through

perforations in the upper part of the inhaler, traverses down through the notches and takes up chloroform vapour volatilised from the bibulous paper, thence it passes up the centre of the inner cylinder into the tube attached to the face-piece. During inspiratory efforts the valve trapping this tube permits of chloroform vapour entering the patient's lungs, while during expiration this ingress valve closes, and the patient freely evacuates his lungs through the expiratory valve. From two to two and a half drachms of chloroform are placed in the inhaler at once, and more added from time to time as this evaporates.

Sansom's Inhaler.—Dr. Sansom has modified Snow's apparatus. The receiver is a cylinder 3 in. high by 1½ diameter, filled with a coil of lint upon which the chloroform is poured. The top is provided with a freely perforated plate through which air passes, to become impregnated with chloroform. The receiver communicates by an exit tube with a face-piece to which are attached inspiratory and expiratory valves. The receptacle is covered with gutta percha which Dr. Sansom believes equalises temperature better than the cold water jacket of Snow.

Junker's Inhaler.—This inhaler, which practical acquaintance with its imperfection has led me to modify, is of value, though it must not be supposed that by its use the patient is placed outside the range of possible danger. In this apparatus, half an ounce of chloroform is poured into a bottle through a funnel-shaped opening fixed in a screw top, air is then pumped *through* the chloroform, and in its passage takes up the vapour. The foot bellows are fixed by straps, one of which slips over the toes, while the other receives the heel in the long loop. When the foot

presses lightly, the air in the bellows is forced through the tube into the bottle, thence through another tube to a face-piece. The net-enclosed ball is for equalising the stream of air and the avoidance of splashing. It is

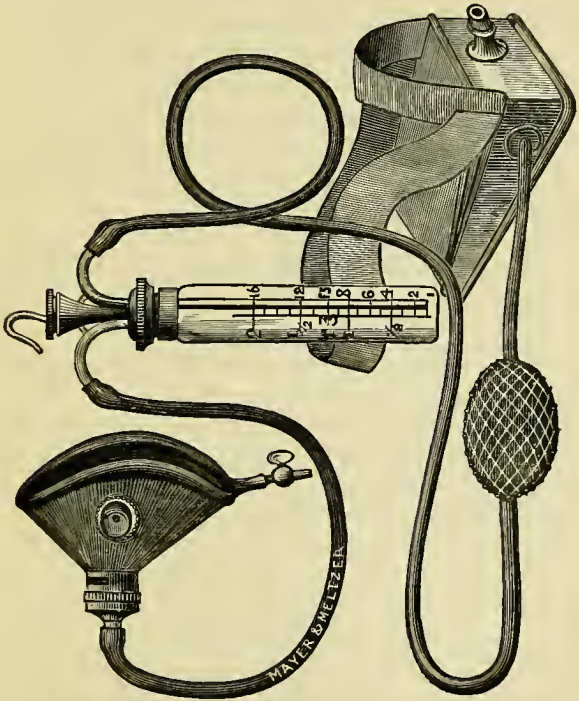

Fig. 9.—Junker's Inhaler for chloroform, improved by Dudley Buxton.

important not to put more than half an ounce in the bottle at once, and not to pump in air spasmodically or too forcibly, otherwise chloroform may be driven through the system of tubes into the face-piece.

Even if this should not happen, a strong blast of chloroform-impregnated air is very unpleasant and deleterious if allowed to impinge upon the face. When the bottle has become nearly empty, the mill-headed stopper which closes the funnel is removed and more chloroform added; thus the apparatus need never be unhooked from the administrator's coat, and the top never unscrewed until the administration is over, when the bottle should be emptied and cleaned.

A simple inhaler used much abroad, consists of a a framework of wire fitting over the nose and mouth and covered with flannel. Chloroform from a drop bottle is allowed to fall upon this while the patient inhales from the concave surface. Although convenient, this inhaler is far from safe, it has no pretension to regulating the percentage of vapour it allows to enter the patient's lungs, and so must be used with the utmost caution.

There are many other inhalers, but most of them contravene the first law of giving chloroform by impeding a free supply of air and failing to regulate the latter to the proportion of chloroform inhaled.

The Open Method.

Lister thus describes the Scotch method:—A common towel is arranged so as to form a square of six folds, and enough chloroform is poured upon it to wet an area the size of a hand's palm, the precise quantity poured on not being a matter of any consequence. The patient is instructed to close his eyes to protect them from the irritating vapour, and the towel is then held as near to the face as can be borne without incon-

venience. More chloroform is added from time to time as occasion requires.

I have found it best to commence the inhalation with a comparatively small quantity of chloroform upon the towel, especially in dealing with children. In a minute or so the sensibility to the irritating vapour is deadened, and the strength of the atmosphere may be increased. As soon as unconscious struggling appears, the narcotic must be pushed, as danger, such as exists during the stage of excitement, is due to the muscular perturbation, and the sooner it is over-powered the less is the patient's peril. When the towel is withdrawn for additional chloroform it should be quickly replaced, but as the vapour then given off will be increased in percentage amount, and as the fresh air entering the lungs during the withdrawal of the towel may induce a deeper inspiration, it is well to keep it a trifle farther from the face for a minute or so. Throughout chloroformisation the respiration must be *constantly* watched, both by regarding the regularity of the rhythm of the thoracic movements, and by testing the amount of air passing from the trachea. Thoracic movements persist for some minutes after occlusion of the larynx or trachea, and so by themselves are no just criterion that sufficient air is entering the lungs. The pulse should be observed, for not only may the heart fail from chloroform depression, but from hæmorrhage, shock, fear, &c. When the exigencies of the operation allow it, the head should be quite low, supported only by one small pillow. This arrangement should be made after the first stage of narcosis, because patients while conscious, like to have their heads pretty high. Fitness for operation is to be judged by the loss of conjunctival reflex. To ascertain this, the eyelids are gently

opened, and the cilia lightly touched with the palm of the forefinger, should no blinking occur, the operation may be commenced. To this rule, children and hysterical females form exceptions. They will often permit this test without flinching, but will evince lively evidence of consciousness if the unwary administrator permits surgical manipulation to proceed. The deep, almost stertorous breathing, the muscular rigidity or complete flaccidity of muscles, will in these cases help out the diagnosis. On the other hand, I have observed in some persons, especially if afflicted with conjunctival or ocular disease, that the conjunctival reflex persists for some time after complete anæsthesia has supervened. The size and mobility of the pupils, although somewhat uncertain in their indications, should yet be observed. In surgical anæsthesia by chloroform they are of normal size and usually sensitive to light, dilating however during emergence from narcosis, and especially before sickness is imminent. But sudden dilatation also occurs when the patient has taken an over-dose and the heart is dangerously depressed. To distinguish between these states needs the utmost caution. In the last condition deep narcosis and its signs will exist, the pulse will be almost imperceptible, and the respiration hampered; while in the first, the patient will give unmistakable symptoms of returning consciousness, which may be accompanied by a flagging pulse. When dilatation of the pupil results from over-dosage, measures to effect restoration must at once be applied, but when due to returning consciousness, a fresh supply of chloroform will prevent vomiting, steady the pulse, and cause the pupils to return to their normal size. This must be done boldly but very warily. If the patient, in spite of all efforts to prevent

him, should vomit, and especially if it be known that he has partaken of solid food within the last two or three hours, the head must be turned aside and free egress given to the vomited matter, and, if necessary, the mouth must be cleared with the finger. The danger to be avoided in this contingency is, lest the vomit be sucked back into the larynx when the patient makes the strong inspiration which always follows vomiting.

When the dilated pupil signals heart failure and cessation of respiration, all the signs of increasing and profound narcosis are present, and then it is that the chloroform must be removed and efforts promptly made to restore consciousness and stimulate reaction (*see* Treatment of Complications under Chloroform).

During the progress of the operation, attention should be paid to the condition of the pupil as above noticed, and to the pulse and respiration.

Although heart failure may occur at any time during chloroformisation, it is more liable to do so quite at the commencement; while more danger arises subsequently from failure of respiration through accumulation of chloroform in the blood, and paralysis of the medullary centres. Weak pulse and shallow irregular breathing indicate over-dosage, and then the amount of chloroform given must be diminished.

The colour of the patient's face, lips, and ears, is a valuable guide to his condition; lividity, cyanosis and pallor, are all indications that danger is present. The operation completed, the patient should still be carefully watched until he has recovered consciousness sufficiently to prevent accidents, from dropping back of the tongue, vomiting, &c. If possible, it is best to allow him to sleep off the effects of chloroform, and it is always a mistake, unless there be some very good

reason, to arouse a chloroform patient from his doze by loud speaking, shaking, putting water on his face, &c. Such procedure often induces vomiting and headache.

Exception has been taken to the open method, upon the ground that it is impossible to regulate the amount of chloroform inhaled, and so to obtain a definite percentage vapour; also because so much vapour escapes from the surface of the towel into the room and prejudicially affects onlookers. Dealing with these objections, Sir Joseph Lister has found after careful and ingenious experimentation, that only sufficient chloroform escapes from the lower surface of the towel to constitute, when mixed freely with the circulating air, an atmosphere of 4·5 per cent., and of this only a portion would enter the patient's lungs. He further believes that inspiration does not affect the rate with which evaporation occurs. Of course these statements are only true as long as the open method is conducted strictly, and with every precaution given in the preceding sections.

Complications arising during the Administration of Chloroform, and their Treatment.

Syncope.—Failure of the heart may occur quite at the commencement of the administration, that is, after two or three inspirations of chloroform vapour, or it may supervene much later—in the third stage. In the primary stage, syncope has been variously accounted for; it has been attributed to reflex inhibition of the heart excited by terror, or by the irritation by the chloroform vapour of the sensory nerves of the pharyngo-laryngeal mucous membrane and pulmonary tract; or

to an individual obnoxiousness to chloroform vaguely called the chloroform idiosyncrasy. Cases have been recorded of sudden death, provoked by fear, in persons about to be operated upon, who have either taken no anæsthetic or have imagined, erroneously, they were being chloroformed, while in reality they were inhaling eau-de-Cologne, or an equally innocuous substance. It is unquestionably highly important that all perturbing causes provocative of fear, such as loud and technical talking descriptive of the horrors of the operation, should in the patient's presence be carefully avoided. No movement, such as uncovering the diseased area, suggestive of the commencement of the operation, should be permitted until unconsciousness is well established. Fear and trepidation must always be met by kindly re-assurance, while haste and brusque handling must be studiously avoided. Nothing can be more prone to produce fatal syncope than the commencement of the operation before complete anæsthesia has been induced, for here we have a lowering of the vital functions caused by chloroform, and the shock of cutting the skin, especially over a sensitive area, communicated along sensory nerves whose conduction is not yet in abeyance. Records of death under these circumstances (incomplete anæsthesia) show how often the fatality arises in cases when trivial, although painful operations, such as reduction of dislocated limbs, circumcisions, &c., are performed. Under these circumstances, too, it must be remembered that the heart is peculiarly liable to reflex inhibition, as vasomotor paralysis occurs antecedently to loss of conduction along the sensory tracts of the nerves and cord.

Symptoms.—Fluttering feeble pulse, sudden stoppage of the heart, extreme and ghastly pallor, with

blueness of the ears and finger tips, wide sudden dilatation of the pupils, and cessation of respiratory movement, usher in this syncope. There is little or no warning of the onset of this heart failure, nor can the most careful preliminary examination give an indication of cases in which it is likely to occur. Persons the subjects of fatty degeneration of the heart, of aortic or advanced mitral disease, are of course always liable to syncope, but the robust and vigorous incur the same risk, and are frequently the victims of syncope occurring in the initial stage of chloroform. Syncope arising at other stages of chloroform narcosis commonly gives more warning; there is a gradual failing of the heart, evidenced by weakened and often intermittent pulse, pallor and cyanosis, cessation of hæmorrhage, and dilatation of the pupils.

Treatment.—Chloroform must be at once removed, the table tilted so that the head lies at a lower level than the feet, and when possible, the legs should be raised, so assisting a return of blood to the heart. The respiration, which will have ceased consequently upon the cessation of the heart's action, must be kept up by the artificial methods of Howard and Sylvester. (See Chap. X.). When the thorax is grasped in expiration, it is well to slip the hand under the costal border on the left side, and so mechanically excite the heart. The chest and throat bared of all clothing, should be slapped with a towel wetted in cold water, and fresh air from an open window allowed free access to the patient. The injection of brandy in *hot* beef tea by the rectum, and hypodermic injection of ether, or failing that, whiskey, especially over the præcordium, should be promptly tried.

The inhalation of **nitrite of amyl** is vaunted as a specific, and certainly in cases of syncope occurring late in narcosis, or after an operation when much blood-loss has occurred, I have seen it do good. The most convenient way of using the drug is to smash a ɱiij. glass capsule and hold it beneath the patient's nose, taking care that artificial respiration is maintained so as to ensure the due entrance of the fumes into the lungs.

Among other measures advocated for counteracting this syncope must be mentioned, **electrical stimulation** of the heart, and **acupuncture** of that viscus.

One electrode is placed over the neck behind the sternomastoid at about the juncture of its lower and middle thirds, while the other is wiped over the præcordium. I am not prepared to say that this step is not more likely to produce inhibition than excitation of the heart muscle: by stimulating the diaphragm to contraction, it may possibly aid respiration. **Acupuncture** of the ventricle with a gold needle is believed to act by exciting that viscus to contract through direct mechanical stimulation.

Syncope arising late in the course of an exhausting operation must be met by the above methods of treatment, and as soon as the patient has rallied sufficiently to be able to swallow, brandy must be rubbed over tongue and gums, and when capable, the patient should swallow sips of brandy in hot strong beef tea, while sinapisms are applied over the præcordium, epigastrium, and calves of the legs. The head must be kept low and any attempt at sitting up interdicted. Reaction must also be aided by hot water bottles applied to the feet and sides, and the flow of venous blood be promoted by firm rubbing of the limbs from the feet and hands towards the trunk. Inversion of the body so that the

feet are in the air, is often of signal serviee in extreme cases of cardiac weakness, wheu there is no reason to believe that the right heart is eugorged.

Asphyxia from Cessation of Respiration.

This may result from (1) Mechauieal, (2) Vital Causes.

Mechanical.—Sir Joseph Lister has shown that one of the most usual and dangerous accidents which occur under ehloroform, is oeclusion of the larynx by the folding together of the arytæno-epiglottidean folds so that their posterior portions approximate, and by elosing upou the base of the epiglottis, prevent any entrance of air. This aeeident is usually evidenced by stertor and irregular respiratory movements, but it may supervene without any such warning, and as the chest movements eontinue, may be overlooked. If permitted to go unrelieved, the impeded breathing reaets unfavorably upon the heart, already depressed by the ehloroform; cardiac rhythm is impaired or eheeked, and the ghastly aspect of the patieut draws attentiou to his danger.

Treatment.—By seizing the tongue with forceps, (Lister employs ordinary artery forceps for this purpose), and dragging it somewhat foreibly out of the mouth, the obstrueting portions of the arytæno-epiglottidean folds are eaused to reeede from the epiglottis, and so leave a free air passage. This manœuvre acts, it is believed, reflexly, and not merely meehanieally.

The Tongue may fall back and so oeclude the laryngeal opening. When the patient is deeply under the auæsthetie, the hyoid bone drops and the tongue is carried back so as to elose the laryngeal ehink. The air is thus prevented from entering, as every inspiratory

effort only sucks back the epiglottis which acts as a valve permitting some expiration but no inlet of air. The thoracic movements continue even when this accident effectually prevents the entrance of air. Usually, but not always, snoring stertor is present under these circumstances.

The signs of asphyxia soon reveal themselves, the face becoming dusky, then blue, and finally a mottled black, the pulse weakens, and unless promptly relieved, the patient dies.

Treatment.—To prevent this accident, the chloroformist should keep a finger beneath the patient's chin so as to check falling down of the hyoid bone. To remedy the danger, it is necessary to pull forcibly forward the tongue, using forceps, and turning the head to one side, so that the weight of the organ shall not carry it backward. If the accident has not been noticed until respiration has ceased, it will be necessary besides the directions given above, to perform artificial respiration; but usually forcibly compressing the thorax once or twice is all that is needed.

Mucus sometimes collects over the upper opening of the larynx, and in persons whose respiratory efforts are not vigorous, may cause suffocation. Insufficient air exchange leads to signs of asphyxia more or less pronounced, the most striking of which is the progressive duskiness of hue. In this case the throat should be sponged out and the chin jerked up, a manœuvre often sufficient to dislodge the pellet of mucus and restore normal respiration.

Entrance of Foreign Bodies into the Larynx or Trachea.

Teeth, natural or artificial, portions of bone, blood clot, masses of new growth, gags, sponges, are liable to drop back and enter the air-passages, or become jammed in the œsophagus and so provoke asphyxia by mechanical pressure. Small or soft substances which enter the larynx may set up spasm and so prevent passage of air, or they may pass into the trachea, with the same result. When suffocation can be attributed to this cause its relief must at once be obtained by performing tracheotomy, and by sucking out blood, clots, masses of growth, &c.*

It is in all cases necessary to examine the buccal cavity, and if any foreign body be found loose it must be duly removed by the fingers or forceps.

Inversion is also of value in cases where it is feared that blood has entered the windpipe. After tracheotomy, sucking the tube is usefully supplemented by inversion.

Insufflation of the lungs by means of a catheter passed through the larynx has been recommended, but it would appear less effectual than tracheotomy and artificial respiration, aided when need be by sucking out blood or mucus from the tracheal opening.

* An instructive case occurred under my charge at University College Hospital. A man from whom the upper jaw had been removed by Mr. Heath, was under operation for a recurrence of epitheliomatous growth, when his respiration suddenly became hampered, and signs of impending suffocation appeared. Tracheotomy was promptly performed, the tube sucked, and several small masses of the growth withdrawn from the windpipe in this way. The man recovered and the operation was completed.

Vital.—Asphyxia may result from over-dosage: the respiratory centre becomes paralysed, the movements of respiration grow more and more shallow, and at last cease. The heart ceases to beat a few seconds after breathing has stopped.

Treatment.—Artificial respiration must at once be practised.

Epileptic Fits may be provoked by chloroform in persons subject to such seizures; they usually appear in the third stage of narcosis.

Hysterical seizures also occur, but they usually appear in the second stage.

The treatment is simply that of preventing the patients from injuring themselves.

(See also Chapter on Accidents of Anæsthesia).

After Effects of Chloroform.

Vomiting.—By attention to the directions given above (Chap. II.), vomiting is rendered less liable to occur. The following further directions, if duly carried out, will tend to the same end. If bilious plethoric persons have their bowels well cleared before taking chloroform they are less liable to sickness. The patient's head should be kept quite low; he should not be moved from the operating table for half an hour after coming to himself, and then the utmost care must be taken to prevent his being shaken or his head raised.

Opium should not be given by the mouth; and unless there is obvious and urgent shock, brandy, ether, and sal volatile must be withheld. No food must be allowed, whether liquid or solid, for at least three hours after chloroforming, and then nothing warm should be taken

until all nausea has vanished. Meat jelly, bread boiled in milk, to which a pinch of bicarbonate of soda is added, or sponge cakes soaked in a light dry sherry, may be permitted after this time; tea, coffee, soaked toast, may be tried, but all indigestible or solid food should be denied until the following day.

(For the medical treatment see After Effects of Ether, p. 62).

Hysteria.—Fits of hysterics are sometimes excited in the neurotic, by chloroformisation; no specific treatment need be adopted. These attacks seldom last more than three or four hours and should cause no alarm. They may occur in either sex.

Jaundice and general biliary derangement in some instances follow chloroform administration. They should be treated upon general principles, and need give rise to no alarm.

Albuminuria and glycosuria of a transient and unimportant character may also follow the use of the drug.

Astigmatism, giving rise to fear lest the sight be permanently injured, has been noticed, but it is doubtful how far we should attribute this condition to chloroform.

Insanity may, in very rare cases, follow chloroformisation of predisposed persons (Savage). (*See* Medico-Legal Aspects of Anæsthesia, Chap. XII.).

CHAPTER VI.

Less Commonly Used Anæsthetics.

Amylene—Ethydene Dichloride—Bromide of Ethyl.

Amylene.

Amylene (C_5H_{10}), a translucent, colourless, thin, mobile liquid, possessed of an odour which is midway between chloroform and ether in pungency, was discovered by Balard in 1844. It has a sp. gr. of ·6549, boils about 102° F. (Watts) although the boiling point varies somewhat; amylene burns with a luminous white flame. Hardly soluble in water, it is freely so in alcohol and ether.

Preparation.—Zinc chloride in concentrated solution is heated with amylic alcohol to 266° F., distilled from a water-bath over caustic potash and afterwards rectified. When mixed with air it explodes on heating, and therefore should not be used in near proximity to flame.

Physiological action.—Snow made some experiments with this substance, and found small animals required 10 per cent. before losing consciousness, that 20 per cent. produced deep insensibility, while 25 per cent. could be respired with perfect safety. With 10 per cent. the "second stage" of anæsthesia is produced, *i.e.*, the mental faculties without being suspended are impaired; occasionally patients remember what occurs during this period, and partial anæsthesia exists. Snow found that "over-narcotism of the heart with paralysis of its muscle" could be attained with

amylene, but that sudden death from this cause was less liable to occur than with chloroform. He found also that 40 per cent. of amylene would be required to effect such a mode of death.

In 1856 Snow employed amylene to produce general anæsthesia. He found it occasioned little or no sickness. The anæsthesia appeared with great rapidity, sometimes before consciousness was lost; the recovery was speedy and usually unaccompanied by headache, giddiness, or other unpleasant symptoms. Dr. Snow did not push the narcotism far enough to induce coma; in most of his patients the ciliary reflex persisted (thus contrasting with the effects of chloroform). The induction of narcosis by this agent is tranquil; save in exceptional cases amylene produces complete muscular relaxation. The pulse is increased in frequency, especially during the earlier stage of amylene narcosis. Respiration is quickened as under ether. The pupils remain of natural size, unless the anæsthetic be pushed, when they dilate. The face flushes and sometimes perspiration bursts out, but the salivary and bronchial secretions are not augmented. A tendency to hilarity evinces itself in some persons just as they are passing into the second stage. Mental excitement is usually absent. Rigidity and struggling seldom occur under amylene, a fact which Snow believed was due to the slighter degree of narcosis needed to induce anæsthesia when that substance was employed. The great volatility (great as ether) and the slight solubility of amylene, make its liberation from the blood very rapid; hence recovery from the effects of the drug takes place with great celerity.

In some persons laughter and singing are provoked, but these phenomena usually pass off if the amylene be withheld for one or two inspirations.

Mode of administration.—The vapour of amylene must be of such a strength as to induce anæsthesia in three minutes; if a weaker vapour be used, no matter how long it is persevered with, it will fail to produce an effect. Snow employed the same inhaler as for chloroform. The patient once well under, Snow applied the inhaler every half minute, otherwise he found consciousness returned.

Amylene may be given in a cone, or by the open method; the last, however, is not well adapted for its exhibition, on account of its extreme volatility.

Snow, after his second fatal case, suggested the dosimetric system for amylene (see Clover's apparatus for giving chloroform).

After-effects and dangers.—Snow found the after-effects were fewer and less severe than those subsequent to chloroform or ether. Sickness occurred twice only out of 238 cases; headache was slight and transient; hysterical symptoms were shown by a few women.

Two deaths occurred in Snow's practice, the 144th and the 238th cases, and were attributed by him to the patient's inhaling too strong a vapour (30 per cent.) of amylene. In Snow's opinion the variation of the boiling point in different specimens fully accounts for these unhappy fatalities.

On the other hand, Thudichum asserts that the samples employed by Snow in these cases really contained no amylene, but were composed of intermediate hydrocarbons.

Treatment.—The steps requisite to avert such accidents are similar to those described under "Accidents during the administration of Chloroform."

Ethydene Chloride.

Ethydeno Chloride (ethydene dichloride), more properly ethylidene chloride, $C_2H_4Cl_2$, has a sp. gr. 1·189, and boils at about 136 4° F. (58° C.); this boiling point is not, however, uniform. Clover used samples with a sp. gr. of 1·225 and B.P. 239° F. (115° C). According to Watts, it is identical with monochlorinated chloride of ethyl, $C_2H_4Cl.Cl$, which possesses a boiling point of 64° C. and a sp. gr. 1·174 at 17° C. It is a colourless transparent oily fluid, tasting and smelling like chloroform. It is prepared from aldehyde by acting upon it with pentachloride of phosphorus. It is also formed as a bye-product in the preparation of chloral, and separated by distillation and subsequent fractionation. Insoluble in water, it is freely taken up by alcohol, chloroform, ether, and oils. It is less inflammable than chloroform.

Dr. Snow was the first to employ this anæsthetic in England (June 20th, 1851) and it was subsequently used extensively by Clover, who I believe, until the time of his death, entertained a very high opinion of it. In Germany, Liebreich, Langenbeck and Steffen have used it and published records of cases.

Physiological action.—The Committee of the British Medical Association have carefully worked out this subject.

Frogs compelled to inhale the vapour become rapidly narcotised (4 minutes). Their hearts, however, beat on unaffected for twenty-six minutes.

Warm-blooded animals speedily passed under the in-

fluence of this ether (4 minutes), and remained narcotised without the failure of the heart. Being exposed and watched while artificial respiration was maintained, the heart showed some slowing, but without any material weakening. In an experiment made to compare ethydene with chloroform, a dog was narcotised with ethydene and the cardiac movements studied. While under this agent no interference with cardiac rhythm was observed; when however, chloroform was substituted, the right heart grew distended and dark, and rapid depreciation of cardiac force occurred. The Committee concluded "practically a dog will live for a lengthened period in a state of complete anæsthesia under the influence of ethydene dichloride, whilst it will die in a short time when chloroform is used."

Blood-pressure is slightly lowered by ethydene, the lowering taking place quite gradually, but after awhile a partial recovery occurs, which is assumed to be due to the heart accommodating itself to the influence of the narcotic.

Respiration is slowed and may become spasmodic and jerky, persisting even when the heart has perceptibly ceased to beat.

Upon human beings, ethydene exercises the following effects:—At first a pleasurable glow extends over the whole body, then within a minute or two the senses are confused, and often singing or whistling is induced. Some muscular rigidity then appears and anæsthesia follows. Patients take a longer time to recover consciousness than when chloroform is used, but they experience fewer after-effects. Thus, as soon as they come to, they can stand or walk (Clover) and are able to express themselves with clearness. No headache usually follows; vomiting is present after about one-

third of the cases of major, and one-twentieth of minor operations. This vomiting is less severe than that which follows chloroform and does not persist so long.

There is sometimes a little convulsive twitching. As the patient passes into unconsciousness, his breathing grows stertorous and his pupils dilate, but if air be now admitted, the stertor will pass off and the pupils resume their normal size. The pulse is liable to flag under ethydene, and hence caution is needed in its employment. In the fatal cases recorded, the patients died from heart failure, the myocardium being pathologically fatty.

Methods of administration.—Mr. Clover who gave ethydene 1877 times with but one death, recommended administrators to commence the inhalation with nitrous oxide and then to prolong anæsthesia by ethydene contained in his ether inhaler. Of course the initiation with gas is matter of choice. When given from an ether inhaler (see article, Ether) the anæsthetic should be pushed until after the stage of struggling has passed, subsequently it should be given far more sparingly, the inhaler being lifted from the face every third or fourth inspiration for the admission of fresh air. The patient becomes anæsthetised in three to five minutes. Dilatation of the pupil and stertor are signs indicative of the necessity of reducing the amount of anæsthetic given. The Glasgow Committee gave ethydene by the open method upon a towel.

Ethydene is also given, through Junker's inhaler, or Snow's chloroform inhaler may be substituted.

Accidents and after-effects.—These are similar in kind to those treated under the article Chloroform to which the reader is referred. (See also Accidents of Anæsthesia, Chap. X.).

Hydrobromic Ether.

Hydrobromic ether (bromide of ethyl) C_2H_5Br, sp. gr. 1·4733, boils at 40·7° C. It is a colourless translucent liquid, with a neutral reaction, ethereal smell, and a pungent sweet taste with a somewhat burning after flavour. When ignited, it burns with a green, smokeless flame emitting an odour of hydrobromic acid (Löwig). It is prepared by distilling alcohol (ethylic) with either bromine, hydrobromic acid or bromide of phosphorus. It is only slightly soluble in water, but freely so in ether or alcohol. Serullas discovered this substance in 1827, but to Nunneley, of Leeds, we are indebted for its recognition as an anæsthetic (1849).

Physiological action.—Rabuteau has made careful researches upon the subject. Non-germinating seeds are unaffected by it, plants die when placed in its atmosphere after a very short exposure. Frogs become deeply anæsthetised when immersed in watery solutions. Upon human beings it produces unconsciousness and anæsthesia in one minute, and complete muscular relaxation in two or three minutes. No suffocation or laryngeal irritation appears to exist, although there is much congestion of the head and neck, and an increased secretion of mucus which may give trouble. The breathing is quickened, the pulse accelerated, and the heart's action somewhat weakened. The pupils dilate. Return to consciousness after withdrawal of the ether is very prompt. Vomiting is said to occur frequently during the administration and even to continue for some hours succeeding.

Blood-pressure, according to Wood, is slightly reduced by small, and very considerably by large quanti-

ties. Where death ensues it is due to cardiac failure (Wolff and Lee); but these statements are denied by some observers. Ott believes ethyl bromide kills by direct action upon the respiratory centre, and does so whether injected subcutaneously or inhaled. The heart failure, he thinks, is secondary to the respiratory trouble.

Method of administration.—Ethyl bromide must be given like Ethyl oxide (Sulphuric Ether), air being excluded. Turnbull who has made careful study of this substance, insists upon the necessity of quickly getting the patient under the influence of the vapour. Owing to the great rapidity with which consciousness returns, extreme attention is needed on the part of an anæsthetist to maintain narcosis. The respiration and pulse require watching throughout the administration. No prolonged operation must be attempted under ethyl bromide, forty minutes being the limit of time during which it may be safely administered.

Suitable Cases for Ethyl Bromide.

Short operations and those of minor surgery.—In dental operations the rapidity with which the patient shakes off narcosis renders ethyl bromide of little more use than nitrous oxide, while it would not seem to equal it in safety. In obstetric practice it is said by Dr. Laurence Turnbull to be of the utmost value, since it rapidly induces unconsciousness and the patient as speedily regains her senses. It must not be forgotten, however, that when bromide of ethyl is given in small doses, much muscular spasm results, which is not desirable in accouchement.

Dangers resulting from the use of Hydro-

bromic Ether.—Richardson, entertaining a very high opinion of ethyl bromide as an anæsthetic, denies that fatalities have followed its employment. Two, if not more, deaths have been stated to have resulted from its administration, but these were in reality due to impurities contained in the sample used. According to Dr. Laurence Turnbull, most of the ethyl bromide sold is impure, containing free bromine, carbon bromide (C_2Br_4), phosphorus, and bromoform. Further, this substance is very unstable and readily decomposes, liberating free bromine. The presence of these bodies renders the impure ethyl bromide singularly dangerous, and until we can be sure of the purity of any given sample I think we are scarcely justified in its use for anæsthetic purposes.

Complications.

Muscular spasm may be so pronounced as to interfere with respiration.

Excitement instead of insensibility may appear.

Persistent vomiting has been recorded as following its employment.

Heart failure may occur.

In no case is it safe to continue the administration of this anæsthetic for more than forty minutes. (Dr. Laurence Turnbull).

Treatment.—The directions given elsewhere (Chap. X.) apply to the recovery of the apparently dead from ethyl bromide. Thus, artificial respiration must be resorted to at once, and the mouth and pharynx cleared of secretion without delay.

Amyl nitrite may be tried.

CHAPTER VII.

Anæsthetic Mixtures.

These are of two classes :—1. Admixtures of members of the alcohol or etherial series. 2. Alcoholic or etherial anæsthetics with alkaloids or other bodies.

The following are the best known and most useful members of the first class :—

The A. C. E. Mixture.—Compound of 1 part alcohol, sp. gr. ·838, 2 parts choloroform, sp. gr. 1·497, and 3 parts ether, sp. gr. ·735.

The Vienna Mixture.—1 part of chloroform to 3 of ether.

The Mixture recommended by Linhart : 1 part alcohol, 4 chloroform.

Methylene.—1 part alcohol and 4 parts chloroform (Regnauld and Villejean).

Billroth's Mixture.—3 parts chloroform, 1 each of alcohol and ether.

The A. C. E. Mixture, which was originally proposed by Dr. George Harley, is strongly recommended by the Anæsthetic Committee of the Royal Medico-Chirurgical Society of London. They speak of its action as midway between that of chloroform and ether. It has been largely used in England, and although not without objections, is a good substitute in many cases when ether cannot be taken. The main objection to the employment of this and all other mixtures is, that substances employed in their formation do not evaporate in the ratio in which the fluids are mixed, and hence

it is impossible to be quite sure what percentage vapour of chloroform is being inhaled. To obviate this difficulty, Ellis proposed to blend the vapours of alcohol, chloroform, and ether, and so administer a true vapour mixture to the patient. The apparatus he used is too complicated for practical purposes, and his method has never received much favour. In three chambers, known weights of the anæsthetics were evaporated; these chambers could at will be made to communicate with a common chamber, and from this the patient was anæsthetised.

Mr. Martindale has proposed an admirable volumetric mixture, the ingredients of which evaporate almost uniformly. It consists of absolute alcohol, sp. gr. ·795, 1 volume, chloroform, sp. gr. 1·498, 2 volumes, pure ether, sp. gr. ·720, 3 volumes.

Method of employing the A. C. E. mixture. This may be given in a Clover's ether-inhaler, a cone, or even by the open method. In the last case, much ether vapour escapes into the surrounding air, causing inconvenience and delay in the onset of insensibility, and further rendering the mixture relatively rich in chloroform while deficient in ether. No special directions are needed if the chapters upon chloroform and ether administration have been read. The fact that chloroform is present in the mixture makes it obligatory that plenty of air be allowed the patient, to effect which the cone or inhaler should frequently be raised from his face. Both respiration and pulse must be carefully noted, as fainting and asphyxial troubles may occur under the employment of the A. C. E. mixture.

After-effects are much the same as those of chloroform or ether. Deaths have occurred during the use of the A. C. E. mixture. Richardson employs a mixture

consisting of 2 parts alcohol, 2 parts chloroform and 3 of ether, affirming it to work well. He has never lost a case during its employment.

The Vienna Mixture (1 part chloroform, 3 of ether), stated to have been employed eight thousand times without a casualty, may be given practically in the same way as ether, save that care must be taken that the patient shall respire fresh air at frequent intervals.

Linhart's Mixture is administered similarly to chloroform; the same care and watchfulness being necessary, as most of the risks of chloroform are present in its use.

The substance called Methylene and stated by Regnauld and Villejean to be merely a mixture of methylic alcohol and chloroform corresponding with Linhart's mixture above given, is a favourite with some. It is more agreeable than ether, possessing the fragrant smell of chloroform. Its safety is probably only that of diluted chloroform, and many deaths have followed its use.

Dr. Richardson, the first who introduced methylene into English practice, writing in the *Asclepiad* (1884), adheres to his original statements in favour of methylene. He holds that although many samples are mere mixtures, yet pure dichloride of methylene is anæsthetic. This is absolutely denied by the French chemists cited above, who state that the pure substance, (bichloride of methylene), is not an anæsthetic, but a powerful convulsant, and proves fatal to animals in a few seconds.

Methods of employment.—Although methylene may be given by the open method, it is more commonly administered from a Junker's inhaler (see description

page 77). Methylene acts precisely like chloroform, and its use is fraught with dangers which differ not in kind, but in degree, from those present when chloroform is used.

Both the respiration and pulse must be sedulously watched, and the utmost vigilance displayed to avoid accumulation of vapour in the lungs. With the use of an inhaler, it is most important to avoid pushing the narcosis too far. When a patient has once become unconscious, the amount of air blown over should be much lessened, thus he can easily be kept anæsthetic with a very small percentage of methylene vapour. It must, however, be borne in mind, that methylene being diluted chloroform, the subject is apt to regain consciousness somewhat more rapidly than during the use of simple chloroform.

The after-effects of methylene are those following the use of chloroform, they are, however, often less severe. Several deaths have occurred during the use of this substance.

Billroth's Mixture (chloroform 3 parts, alcohol and ether, each 1 part), is but little known or employed in England. It contains a high percentage of chloroform, and hence needs careful handling. It should be administered either by the open method, or if an inhaler be used, Junker's or the simple flannel cap will answer. In either case the patient must be allowed plenty of fresh air.

Similar dangers are imminent, and precautions needed, as in the administration of chloroform. Deaths have occurred during the use of Billroth's mixture.

Mixtures of Chloroform or Ether with Alkaloids, etc.

Chloroform and Morphine (Nussbaum).

Injections of morphine, gr. $\frac{1}{6}$ to $\frac{1}{2}$, or in some cases more, hypodermically, half an hour before giving an inhalation of chloroform, possess the following advantages:—Less chloroform is needed, while the stupor is more prolonged. If the morphine be given immediately before, it prolongs the period of excitement. Drunkards, and persons who show little amenity to chloroform, soon pass under its influence after a dose of morphine. The patient is usually more completely relaxed and passive, the breathing is quieter, and it is stated, (Kappeler), that the depressant action upon the heart is diminished.

The stage of excitement is shortened, and cerebral circulation while under morphine is markedly lessened, so that for operations involving the opening of the meninges and the cutting of the brain substance, this combination is most valuable.

Excitable persons about to be anæsthetised will often be calmed by morphine.

Upon the other hand, vomiting is more frequent when morphine is used. Poncet, from a wide experience during the Franco-Prussian war, abandoned the method, owing to the frequency with which prolonged stupor occurred after its use.

Morphine in some produces great excitement, and this by the addition of chloroform may be magnified to a very inconvenient extent.

When this combination is employed, it is important to restrict the amount of chloroform given; indeed when

the patient is once fairly narcotised, very little more chloroform will be needed unless the operation be a very prolonged one. Care must be exercised that only a weak vapour is used since the patient will take but little notice of its pungency, and so one of the usual safeguards is lost. Caution must also be displayed in employing this mixture when severe hæmorrhage is likely to take place into the pharynx, as the patient is not easily roused, and the danger of blood entering the lungs is increased.

Demarquay has very justly indicated that the chief dangers of this method of mixed anæsthesia lies in want of caution in not limiting the dose; large injections of morphine preceding chloroform administration certainly have a danger of producing asphyxia.

It was pointed out some years ago that atropine in paralysing the vagus might be a valuable antidote to chloroform, by preventing reflex inhibition of the heart through the par vagum. I have found the addition of gr. $\frac{1}{120}$ of atropine to gr. $\frac{1}{4}$ of morphine to be an advantage, when that last alkaloid is employed synergetically with chloroform.

Morphine and Ether.

It has been proposed to exhibit morphine before ether, similarly as before chloroform, but the method possesses disadvantage in its liability to induce prolongation of the stage of excitement. It may induce very violent struggling and increase the after-headache, prostration, and vomiting. Kappeler, who has experimented with this mixed method, states that he has completely failed in several cases in which he attempted to narcotize patients with ether subsequently to hypodermic injections of morphine.

It is not, however, clear whether Kappeler's results should be considered quite so absolute as his statements would lead one to suppose. Certainly in cases at University College Hospital in which the method was employed, no great struggling or inconvenience was observed.

Chloroform and Amyl Nitrite.

American physicians have employed this mixture and speak well of it, and Dr. Richardson in this country has lent it his support.

It is claimed that chloroform, when mixed with nitrite of amyl in a proportion of one pound to ʒ ij. (Sanford), or an ounce to ♏xvj., loses many of its dangers, and is more agreeable to take.

Upon the other hand, we are compelled to recognise that such a mixture possesses several undeniable objections. In the first place the sp. gr. of chloroform is 1·497, that of nitrite of amyl, ·877, so no permanent mixture can be maintained, a drawback which even a suggestion to "shake the bottle well before use" does not abrogate. Again, nitrite of amyl cannot, as is asserted, be considered a physiological antagonist of chloroform, for the following reasons:—Nitrite of amyl lowers blood pressure by producing paralysis of either muscular coatings of the vessels or of the vasomotor ganglia controlling them. After an initial fillip to the heart's action it depresses, and may if pushed even cause syncope. In animals, the heart muscle is after a time paralysed. Further, the respiratory centres are depressed, while the motor centres in the spinal cord are paralysed. It would thus appear that so far from nitrite of amyl opposing the depressant action of chloroform, it probably acts similarly, and by adding it

to that narcotic we are still more prejudicing the patient's chances of recovery, If it be urged that successful cases of administration stultify any such theoretical reasoning, the answer lies in a consideration that, firstly, the combination was probably never a mixture and so the patient inhaled chloroform and little if any of the amyl nitrite; and, secondly, that just as we find very many persons whose hearts withstand the stress of chloroform depression, so many would survive the still greater depression of chloroform to which is added amyl nitrite. I cannot find records of any instances in which prolonged anæsthesia was maintained by this mixture. In brief operations it would be at its best; but then it is in lengthy operations that the depressant action of chloroform is to be most feared.

Method of employment.—The method of employing this mixture is similar to that of chloroform.

Chloroform and Chloral.

The preliminary giving of chloral was first suggested by Forné; it is said to curtail the period of excitement and to produce an anæsthesia comparable to that which ensues when morphine is used in conjunction with chloroform.

Dose.—Perrin used as large a dose of chloral as gr. 45 for adults (three grammes) before chloroforming. An alternative plan has been suggested, viz., to divide the dose, giving half by the mouth and half by the rectum. Children of course would require a much smaller dose.

I cannot think the advantages which are alleged for this method in any way counterbalance the dangers which undoubtedly attend its employment.

Chloral Hydrate and Ether.

Kappeler used chloral hydrate in forty grain doses (children half this quantity) as a preliminary to the inhalation of ether. The duration of anæsthesia was prolonged and the recovery retarded, while vomiting, headache, and prostration, were more severe than when ether only was employed.

Priestley Smith (Heath's *Dictionary of Surgery, Art.* Cataract) gives fifteen or twenty grains of chloral hydrate twenty minutes before administering ether, and finds this practice answers well in operations for cataract.

A death (Lyman) has followed the use of this combination.

Nitrous Oxide and Ether.

This combination is fully described under "Nitrous Oxide," p. 30. It is the best method of producing general anæsthesia. When complete unconsciousness has been attained by giving nitrous oxide, the duration may be prolonged by allowing the gas to pass through the ether; or by turning off the gas altogether, the patient may be kept anæsthetised by ether for a lengthened period.

Clover's Gas and Ether Apparatus enables one to regulate the supply of gas or ether with a nicety and precision unattained by any other instrument. The dangers and precautions incident to this method are those fully described in the chapters upon Nitrous Oxide Gas and Ether.

CHAPTER VIII.

Anæsthetics in Obstetric Practice.

Whether or not an anæsthetic should be administered in parturition, is for the accoucheur to decide. In cases which are considered suitable, it becomes the anæsthetist's duty to render his aid.

Choice of anæsthetics, stage when to be administered, etc.—As a rule chloroform is preferable to ether, unless an operation is to be performed, or unless the patient is greatly depressed by hæmorrhage or shock. Snow advised that chloroform should be withheld until the *os uteri* was fully dilated and well marked expulsive pains had appeared. He, however, made an exception to this rule, when during an earlier stage the pains were very severe.

Spiegelberg, in summing up the advantages of an anæsthetic in obstetric surgery, says chloroform not only allays the pangs of childbirth, but checks bearing-down and diminishes the tension of the abdominal and pelvic muscles as well as that of the uterus. He further extols its use in neuralgia and cramps occurring during parturition.

In normal labour little chloroform is needed; if a very dilute vapour is inhaled the patient sinks into a quiet sleep, and her sensibility to pain is decreased. The uterine contractions are unaffected, but although during the pains the woman may groan and turn over, yet her complaints are but slight, and as soon as the pain passes off sleep again comes on.

Rules guiding the administration :—

1. Quietude in the room is essential; fresh air should from time to time be admitted, and the patient's posture should be unconstrained.
2. Chloroform should be administered between the pains. It should be commenced when the labour is in its second stage if the pains are very severe, but if they are not it is best to wait until the fœtal head is on the perinæum. As a rule the chloroform should not be given during the intervals, unless the severity of the pains is very great, or it is deemed advisable to induce deep anæsthesia for the performance of an obstetric operation.
3. When the patient becomes excited by the chloroform, if it is considered really essential that she should be anæsthetised, it must be pushed to complete narcosis.
4. When the labour is protracted and the patient is to be kept anæsthetic, it is necessary to cease the inhalation from time to time, otherwise an injurious accumulation of the drug will take place.
5. When an obstetric operation becomes necessary deep anæsthesia must be obtained (Charpentier).
6. When heart, lung, or kidney disease exists in a parturient, the production of anæsthesia is dangerous, and its advisability must be settled upon the same general principles which guide us in deciding upon like cases in surgical anæsthesia.
7. It is necessary when the patient is kept semi-narcotised to carefully guard against over-distension of her bladder.
8. It is inexpedient to awaken the patient to consciousness by artificial means, *e.g.*, slapping with a wet towel.

These rules may be supplemented by those urged by the Chloroform Committee of the Royal Medico-Chirurgical Society.

When the fœtal head bears on the perinæum give the anæsthetic more freely, as it relieves the increased pain and also dilates the maternal passages.

If the patient is depressed or the pains are sluggish during the administration, an occasional stimulant may be administered.

In cases where it appears to interfere with the progress of labour, it may be necessary to suspend its use for a time and re-apply it after an interval or even to withdraw it altogether. If a meal has been recently partaken, avoid chloroform, the sickness likely to follow will impede delivery.

In *primiparæ* it must be given very moderately.

Objections.—These, although strenuously urged by some, are probably more theoretical than real.

1. It is said to increase the mortality alike among mothers and children.

Statistics certainly negative this statement. It has been averred that the danger to the parturient is in direct proportion to the amount of pain experienced, and since chloroform minimises this, it lessens the actual danger of childbirth.

2. It is asserted that it protracts the labour.

Unless pushed to the degree of deep narcosis chloroform does not interfere with uterine contractions. In experimental researches upon animals this point has been fully proved and has recently been corroborated in a striking manner by Dr. Milne Murray of Edinburgh.

Deep narcosis renders the voluntary abdominal muscles lax and so interferes with expulsive efforts. Very deep narcosis also paralyses the uterine muscular tissue.

On the other hand a womb, exhausted by frequent and ineffectual contractions, will often under chloroform regain tone and resume vigorous expulsive movements.

3. Rupture of the perinæum is said to follow more commonly when chloroform is used.

I have never seen satisfactory proof of this allegation, and can find no valid reason why such an accident should be associated with the anæsthetic state.

4. Complications are asserted to be more liable to occur when it is used.

This point was carefully investigated by the Chloroform Committee of the Royal Medico-Chirurgical Society and it was found that chloroform when properly administered does not predispose to inflammation, puerperal convulsion, apoplexy, or other mishap; indeed, as it promotes dilatation of the maternal passages, it is beneficial.

Opinions differ as to whether it predisposes to imperfect contraction of the uterus and so to *post partum* hæmorrhage. This question is greatly influenced, firstly by the degree of narcosis arrived at, and secondly by the length of time allowed to elapse before its use, as well as that during which it is employed. Prolonged use of small doses may be more harmful in this respect than deep narcosis arrived at rapidly and not maintained for more than a few minutes. It is also highly important that the patient's respiration should be free and unhampered by her posture. Lactation is not injuriously affected; the child is in no way injured.

Convalescence is not only not delayed, but is in point of fact actually hastened by the use of chloroform. This statement is made upon good authority and is probably explained by the fact that by the use of chloroform the nervous system is protected from shock. (Sansom).

Method of exhibition.—The open method, a piece of lint or a towel, answers best. Some practitioners let the patient hold a piece of lint or a cup inhaler so that when they grow drowsy the improvised inhaler drops from the hand. Care must be taken that the face does not fall over the chloroformed cloth, or the breathing become impeded by the pillow or bedding.

"When deep anæsthesia is required it is best to have a skilled administrator." (Chloroform Committee).

In the first stage of labour, chloroform or the A. C. E. mixture, if required at all, should be given intermittently and in small quantities. As a rule the first stage of narcosis is deep enough. The patient is conscious, but only slightly alive to painful sensations. If any excitement and disorderly conduct follow, the patient must be allowed to recover her self-control. Some persons need more chloroform than others, so that the administrator must decide each case upon its own merits and further must be guided by his own observations, and not influenced solely by the patient's cry of "Give me some more." Women frequently repeat this phrase when almost unconscious and unaware of preferring any request. In the second stage, chloroform should be given only during the pains, and then merely to slight narcosis since the woman needs the use of the abdominal muscles. At the stage of labour when the head is traversing the perinæum, deeper narcosis is needed to relax the soft parts, whilst at the last as the head emerges through the vulva, chloroform should be freely administered.

When instrumental procedure is requisite deeper narcosis is needful and especial caution is required in order to prevent the patient being made simply excited and rigid, a condition alike dangerous to the

mother and child. This stage must be rapidly got over and true anæsthesia obtained.

Obstetric Operations.

For *Turning* and instrumental deliveries, if an anæsthetic is employed, deep anæsthesia is requisite and may either be accomplished by chloroform or ether. The London Committee approved the former, but mainly on account of the greater ease with which it was then exhibited. Since our modern appliances for ether-giving are so improved this reason can have no weight. In deep narcosis from chloroform the parturient is placed in the same danger as for any surgical operation. It is sometimes urged against ether that it does not relax the uterine tissue so effectually as chloroform. If this objection is valid it tells also the other way, as hæmorrhage would under such circumstances be less likely to be severe. The ether effect passes off more rapidly.

The **A. C. E.** mixture is largely used in obstetric practice and answers remarkably well.

For extraction by forceps narcosis sufficiently deep to keep the patient quiet is needed.

Craniotomy.—The narcosis must be deep.

Hour-glass contraction—Retained placenta. Here complete relaxation is necessary and so chloroform must be pushed.

Puerperal convulsions.—Chloroform is indicated in cases of reflex (local) origin, and in hysterical and hystero-epileptic nature. It is contra-indicated in apoplectic seizures.

After Effects.

Vomiting is rare; faintness, excitement, headache have sometimes been manifested, but as a rule few unpleasant results follow the use of chloroform for childbirth.

CHAPTER IX.

Anæsthetics in Special Surgery.

Brain Surgery.—The method which answers best when the brain itself is made the subject of operation, is to administer a dose of morphine, beneath the skin, one quarter of an hour before the operation, and subsequently to administer chloroform. It is necessary to get the patient completely anæsthetised, but when once this is achieved very little more chloroform is needed.* Ether produces too much vascular excitement in the meninges and brain substance, and so is contra-indicated in these cases.

Anæsthetics in Ophthalmic Practice.

Since the introduction of cocaine, many operations about the eye are performed without the employment of general anæsthesia. The extreme steadiness and immobility needful in these delicate operations, require very deep narcosis, and so it is the administrator's duty to push whatever vapour he is using to profound narcosis. The operator must not be allowed to commence his manipulation until the patient is not only absolutely unconscious and flaccid, but shows not the slightest inclination to cough, vomit, or struggle. It

* I am indebted to my friend and colleague Mr. Victor Horsley, F.R.S., for this method in Brain Surgery; I have employed it for his cases with great success.

must be kept in constant remembrance, that the very salvation of the eye depends upon the unflinching immobility of the person of the patient. The nature of the anæsthetic used is of less importance than is the way in which it is pushed.

Anæsthesia for Operations about the Mouth, Jaws, and Respiratory Tract.

Chloroform is preferred (1) because under its use the narcosis is deeper and more prolonged; (2) its vapour is not easily ignited: (3) it can be conveniently given through the nose.

In removal of sequestra from the jaws, excision of epulides, tapping antral abscess, etc., no very deep narcosis is requisite and the patient may be kept sufficiently quiet by the use of chloroform given by the open method.

In **removal of the upper jaw,** the patient must be kept deeply under the anæsthetic for the skin incisions, and this may be done by first narcotising by the open method and by subsequently keeping up the supply of chloroform through a tube introduced into the free nostril and fed with chloroformized air from a modified Junker. When the skin flaps and soft parts are freely divided and dissected up, the patient must be allowed to recover sufficiently to cough and so prevent blood entering the larynx, although he must be sufficiently anæsthetic not to struggle. The management of these cases needs constant care and some judgment. The dangers the chloroformist has to guard against are—entrance of blood, teeth, portions of growth, spicules of bone, etc., into the larynx. It is his duty to see

that the hæmorrhage is directed out of the mouth, that the tongue is not allowed to fall back, that the air enters and leaves the glottis freely. If the patient's respiration is embarrassed, the tongue must be drawn right out of the mouth, all blood mopped away, and failing relief from this, laryngotomy must be performed and the tube sucked free from clots, etc. Inversion may be needed.

Removal of the lower jaw may often be done almost completely while the patient is under ether, chloroform being administered only just at last when in the course of the operation the mouth is opened. This is an admirable method.

In excision of the tongue.—Chloroform administered through a nasal tube should be relied upon and much the same precautions with regard to hæmorrhage taken, as in anæsthetising for removal of the jaws. When much hæmorrhage occurs, the patient must be guarded from deep narcosis.

Staphyloraphy is best performed under chloroform, which is preferably administered through the nostril. Care must be taken that the nasal tube does not get into the operator's way, and to avoid this possibility, a flexible catheter should be used. The hæmorrhage being, as a rule, slight and easily controlled, there is no particular fear of blood trickling down the trachea, and further, as quietness is very desirable in the patient, full surgical narcosis should be maintained. However, with careful management and with frequent interruption of the operation, ether or the A. C. E. mixture may be used. Warrington Haward, to whose powerful advocacy the ether propaganda owes so much, speaks highly of ether in staphyloraphy.

Post-Nasal Adenoids.

Growths in the post-nasal region, when removed through the mouth, give rise to troublesome bleeding. Chloroform, preferred by many surgeons, possesses the disadvantage that the patient remains longer under its influence, and so it is less easy to avoid blood entering the air passages. The additional time is by some deemed an advantage, as it permits of longer manipulation in the mouth. I have found that when it is undesirable to use chloroform, the A. C. E. mixture in succession to gas answers fairly well in these cases. It does not excite as much hæmorrhage as ether, and the patient can, if necessary, be again and again anæsthetised, after emptying his mouth of blood, until the operation is complete. By this method there is not much fear of blood being sucked into the larynx.

Ether possesses the disadvantage of producing much congestion, and so increases to an annoying degree the hæmorrhage incident upon operations for the removal of post-nasal growths. Of course where the cautery is used in the nasal passages, ether must not be used.

Anæsthetics in Dental Surgery.

The operations for which an anæsthetic is usually needed are :—

Extraction of teeth.

Lancing the gums, and tapping the antrum.

Extirpation of the dental pulp.

In tooth extraction, nitrous oxide gas—alone, or with

ether after the manner introduced and advocated by Clover—is the safest and most convenient anæsthetic.

The administrator stands to the left side of the patient and carefully fixes his prop (gag)* either on the side opposite that from which the teeth are to be drawn, or between the central incisors—thus allowing room on each side. The patient is then anæsthetised (see section "Nitrous Oxide"), and when quite unconscious, the mask is allowed to drop, and the patient's head steadied and moved into the most convenient posture for the dentist. Care has to be taken that the tooth, or a fragment from a broken forceps, does not fall back into the larynx, and that the tongue is not pushed back by the operator and the patient's breathing stopped.

As a rule, it is inadvisable to administer gas twice to the same patient at one sitting, but if such a thing is done warning of probable after headache should be given.

Where prolonged anæsthesia is required, ether should be given, and the ordinary precautions taken as for etherization in general surgery. Chloroform should never be given to a patient sitting upright in a dental chair. If it is deemed wise to employ that agent, the patient should be seen at his own home, and in bed, and the anæsthetic administered with the usual caution.

For special dangers of anæsthetics in dental surgery see Nitrous Oxide, accidents under, p. 38, and Accidents of Anæsthesia, Chap. X.

* In this case great care must be taken to avoid the teeth being loosened or forced out of their sockets by the prop.

Anæsthesia in Abdominal Surgery.

Complete relaxation of the recti and other abdominal muscles is imperative; great quietude and freedom from hurried respiration, coughing, and vomiting, are also necessary for operations upon the abdominal parietes or viscera. To ensure these points, chloroform, the A. C. E. mixture, or methylene, are most suitable. During the incisions through the parietes, the patient must be kept fully under the anæsthetic, subsequently a lesser degree of narcotism is needed until the final skin sutures are put in, when deeper anæsthesia will again be requisite. Great care must be taken, however, that the patient is not allowed to recover sufficiently for the supervention of vomiting. In cases in which a large tumour or collection of fluid or gas is removed from the abdomen, and the heart—previously displaced—is allowed suddenly to right itself, there is especial danger of syncope, and precaution must be taken.

Rectal Surgery.

All operations about the anus and rectum are not only very painful, but excite reflex straining and spasm. In anæsthetising for such operations, profound narcosis is needful. The combination of gas and ether in most cases answers well, although it is necessary to give enough ether to induce absolute muscular flaccidity, snoring respiration, and widely dilated pupils—and further, to maintain deep narcosis to the end of the operation.

CHAPTER X.

The Accidents of Anæsthesia, and How to Treat Them.

I. Those connected with Respiration.

Foreign bodies may become loose in the mouth, and either get sucked into the larynx and thence enter the trachea, or become impacted, and set up laryngeal spasm.

False teeth.—Small plates are especially dangerous, whilst obturators and pivots may also become sources of peril. During operation, teeth or pieces chipped off teeth may fall back, and even portions of epitheliomatous or other growth, blood clot, vomited undigested solid food, gags, portions snapped off forceps, and bits of sponge, may obstruct breathing. When the tongue is partially removed, the stump is liable to fall back and cover the glottis, and similarly after removal of a portion of the lower jaw, the whole tongue may be carried back by its own weight. This may also occur in deep narcosis, even when the jaw is intact. The finger inserted in the mouth during tooth extraction, often pushes the tongue right back, and unless this is noticed and remedied, complete occlusion of the air-way occurs.

Precautions.—Remove all loose bodies from the mouth before operation. Let the patient avoid any solid food on the day of operation. Never operate again until the first tooth extracted is known to be *out*

of the mouth ; and be careful that the forceps are freed from the tooth just removed, before employing it again. Gags and sponges must be securely tied to a long string. When possible, the head should be placed on its side, to obviate the effect of the weight of the tongue in carrying it back, and also to facilitate the expulsion of blood. Sometimes a Carter's oral spoon held in the mouth during tooth extraction prevents teeth flying back and being drawn into the larynx.

Respiration may also be **hampered** by the posture of the patient, by pressure upon his chest from instruments, assistants leaning upon him, or by tight bandaging. When placed prone or upon the side, feeble people, those who are fat or emphysematous, or who have fluid in their chests, one lung being more or less hampered, must be carefully watched, as the mechanical interference with breathing in these cases has caused fatal accidents.

All general anæsthetics eventually **paralyse** the **respiratory centre** in the medulla oblongata, and so cause cessation of breathing; but some act more rapidly, and provoke spasm of the glottis by the impact of their too strong and pungent vapour upon its delicate mucous membrane. In this way no air enters the lungs, although irregular thoracic movements persist. Spasm of the larynx certainly may occur from ether or chloroform vapour, and, it is stated, from nitrous oxide gas. As a rule the spasm passes rapidly off, being relieved by the admission of air, but it may be sufficiently severe to need laryngotomy. Chloroform also acts upon the larynx in another way whereby the air-passage becomes occluded ; namely, by the closure of the arytæno-epiglottidean folds. In this case respiratory movements still continue.

Patients may be actually asphyxiated by the administrator excluding all air; and this may occur with any inhaler unless caution is taken and the colour of the face watched.

Treatment.—The foreign body, if still free in the mouth, should be dislodged by bending the head forward and sweeping the buccal and pharyngeal cavities with the finger. Do not pull the tongue forward, otherwise the tooth, or whatever it is, will enter the trachea. Should the finger feel the body fixed, its removal must be attempted with œsophageal forceps or a snare. A slap on the back often helps the expulsion of the offending substance. Inversion should also be practised, although if the body has already passed the larynx there is danger of its falling upon that chamber and giving rise to spasm. Should this occur, or should suffocation be imminent from other reasons, the windpipe must at once be opened as follows:—

The operator feels with his finger for the cricoid cartilage, and makes his incision through the skin and subcutaneous structures for a distance of two and a half inches vertically downwards making the cricoid cartilage the centre of this incision. The assistant draws open the wound with blunt hooks, taking care to pull equally on the two sides, as it is all important that the surgeon should have the middle line well defined for him. Vertical incisions are then made until the deeper structures are divided. The fascia uniting the edges of the sterno-thyroid muscles has to be sought and divided. This done, some veins, the thyroid plexus, come into view, and may be held aside with hooks, but should they be large, clamp forceps may be used to secure them before section, and they can later on be tied at leisure. The isthmus of the thyroid body

may present and hide the trachea, but after dividing its fascia, it can readily be hooked down out of the way. The trachea reached, it is well cleaned with a blunt director and fixed by means of a sharp hook introduced between the rings to the side of the middle line, and with its point looking upward. The trachea is then freely opened by introducing the knife *from below*, and slitting upwards two or three of the tracheal rings, even the cricoid cartilage may be divided, then the aperture held freely open by means of blunt hooks. Succussion, or better, tickling the tracheal mucous membrane with a feather will induce violent expiratory efforts, and may provoke expulsion of the foreign body by coughing. Further measures such as the introduction of fine forceps, snares and so forth are matters hardly within my province to describe. The main object of tracheotomy in these cases is to ensure an air-way should the laryngeal space be closed by spasm, excited by the foreign body either impacted or coughed against it. The operation itself greatly increases a chance of the patient's coughing up the object, because the artificial opening is insensitive and offers an unobstructed outlet, whereas the sensitive larynx closes as soon as touched, and so effectually prevents the coughing out of the foreign body. After the foreign body has been removed a small dossil of wet lint should be placed over the opening.

When mechanical impediment to respiration is not due to a foreign body in the air passages, the tongue must be drawn forward with forceps, until it protrudes well out of the mouth, while at the same time the head is thrown back to straighten the respiratory tract. This treatment will usually be effectual when the tongue or larynx is the cause of non-entrance of air.

When **spasm** of the **larynx** results from administering an anæsthetic, and persists after drawing forwards the tongue and hooking up the larynx, laryngotomy must at once be performed. No formal operation is needful, the surgeon at once incising the crico-thyroid membrane and maintaining open the aperture so made. It is suggested by some that inhaling chloroform relaxes the spasm, but it is of course useless to adopt such measures if the rima is quite occluded, as no vapour will enter, and valuable time is being lost.

If, after the upper air-ways have been cleared and rendered patent by the manœuvres above cited, the breathing still remains unsatisfactory, artificial respiration must be at once practised by one of the following methods.

Sylvester's Method.*

The head is to hang back, with the neck extended, and the tongue held firmly out of the mouth. The operator stands behind the patient and grasps the arms *near* the axillæ in such a way as to evert them and render the pectorales majores tense. He first presses the arms into the sides so as to compress the thorax and expel air, whilst at the same time an assistant should make pressure upon the abdomen to prevent the increased intra-thoracic pressure from forcing down the diaphragm. Next, he firmly drags the arms away from the sides, everting them and lifting the patient as the arms become about 45° beyond the head; finally, he carries the arms back to a line with the head. He pauses to

* The method described is modified by the introduction of the essential features of the plans proposed by Pacini and Bain.

allow air to rush freely into the lungs, and then brings the arms down to the sides as before. This process he repeats twelve or sixteen times in one minute. The way the arms are grasped is important. When they are held below the elbows, it is not possible to open out the chest as effectually as when the method above indicated is followed.

HOWARD'S METHOD

Can be usefully employed, supplementally to Sylvester's. It is also of value when the patient's chest is rigid. The patient is between the operator's knees. The latter, who faces him, applies his hands so as to grasp the free margin of the thorax, his thumbs resting upon the xyphoid cartilage. The patient's arms are drawn above his head. The operator presses upwards and inwards towards the diaphragm, gradually bending over the patient so that all the weight of his body aids in compressing the thorax. After steady pressure for some seconds with a sudden push up the operator throws himself back into his first posture, while the resiliency of the lungs causes their expansion. The process is repeated twelve or sixteen times a minute.

All measures in artificial respiration must be adopted quietly, firmly, and slowly; since crowding, hurry, fuss and inexpertness, are very dangerous. Life may be restored after an hour's artificial respiration.

II. Accidents connected with the Heart and Blood-Vessels.

Syncope may occur as the result of fright, or be caused by sudden impact of a strong vapour upon the air-passages. This occurs in the early stages of the administration, and is shown by pallor of countenance and failure of pulse.

The patient should at once be placed supine, the legs and arms raised, and the head dropped below the level of the trunk; all clothing loosened; smelling salts, liq. ammoniæ fort. (with caution), or burnt feathers be put to the nostrils; and the præcordium rubbed with a warm hand. Sulphuric ether may be hypodermically injected over the heart, and nitrite of amyl capsules be smashed and the patient made to inhale the fumes. If the breathing flag, artificial respiration must be at once practised. An enema of brandy—℥ ss. in ℥ ii. of warm beef-tea or gruel or starch—may be tried. When the patient has recovered sufficiently to swallow, hot strong coffee with a teaspoonful of Cognac should be given. The most stringent injunctions must be laid down that the horizontal posture be maintained until the heart has quite recovered itself.

Syncope occurring later on, may arise from shock from prolonged operation, or loss of blood, or over-taxing of the heart due to respiratory difficulties. Chloroform, given over a lengthened period, also depresses the heart and may determine syncope.

The treatment rehearsed above applies also to these cases; in them it is usually more common to find a *gradual heart-failure* occurring, and giving warning of trouble. Respiration also is especially liable to flag at

the same time as the heart fails. It is especially necessary to have resort to artificial respiration early, both on these accounts and because that measure even by itself will frequently steady the heart and restore its rhythm. In all syncopal attacks, while the above measures are being adopted, an assistant should pour cold water over the face and chest and dash the latter with a towel end, wrung out in ice-cold water.

Apoplectic seizures.—Besides ceasing from all interference and placing the patient supine, little can be done, and directions would not be in place in the present manual.

Epileptic seizures.—The patient should be laid down, his tongue be guarded from being bitten, and his clothing loosened. The only interference justified is to be directed towards restraining the patient from doing himself any injury.

Hysterical seizures should be treated in a similar way to that indicated above (Epileptic Seizures).

CHAPTER XI.

Local Anæsthesia.

It has been sought to obtain local anæsthesia without disturbance of the mental faculties, and this object has been consummated with partial success in three ways.

(1) By drugs painted and injected at the situation desired to be rendered anæsthetic. (2) By cold. (3) By electricity.

The most usual means of producing local anæsthesia by drugs is the use of cocaine. This, the active principle of the leaves of erythroxylon coca, has since 1880 come into use for producing local insensibility to pain. It is employed commonly in two ways: *a*, as a paint over mucous or cutaneous surfaces, and *b*, by subcutaneous injection.

Physical Properties, Preparations, etc.

The alkaloid cocaine ($C_{17}H_{21}NO_4$) has a bitter taste; forms crystals; is with difficulty soluble in water, freely so in chloroform or ether, also in melted vaseline, castor oil, etc. With benzoic, citric, hydrobromic, sulphuric, tannic, oleic, and hydrochloric acids, cocaine forms salts, respectively, the benzoate, citrate, hydrobromate, sulphate, tannate, oleate,* hydrochlorate, of cocaine, which possess the advantage of being easily soluble in water, and so readily employed for hypoder-

* A saturated solution of cocaine in oleic acid.

mic injection. Aqueous solutions of these salts should not be kept any length of time, as they are liable to become contaminated by the growth of a fungus which occasions deleterious effects upon the patient. The addition of boric acid, carbolic acid, or chloroform has been suggested to prevent such fungoid growth, but these cannot be relied upon to promote the object in view.

Physiological Action of Cocaine upon Heart and Vessels.

In cold-blooded animals cocaine, whether applied to the heart itself, circulated through the detached ventricle, or injected into the circulation, slows the rhythm and depresses the beat, finally arresting the heart in diastole. The accompanying trace—the detached heart of a frog, being circulated with cocaine 1 in 2000 of a competent fluid—shows the power of this drug as a cardiac depressant. (Fig. 10).

Cocaine also interferes with cardiac innervation, decreasing in a very marked degree the excitability, for while it abolishes "make" contractions, "break" contractions persist. Although both auricles and ventricles are influenced, the latter are more interfered with, and cease to beat before auricular rhythm is arrested. (Van Anrep).

The blood-vessels are but little, if at all, affected by cocaine unless it be applied locally as a paint, and in this case it is doubtful how far the action is really characteristic of the drug.

In warm-blooded animals, an initial increase in rapidity of the heart's beat occurs, the heart's action is weakened, but usually recovers and is said to sur-

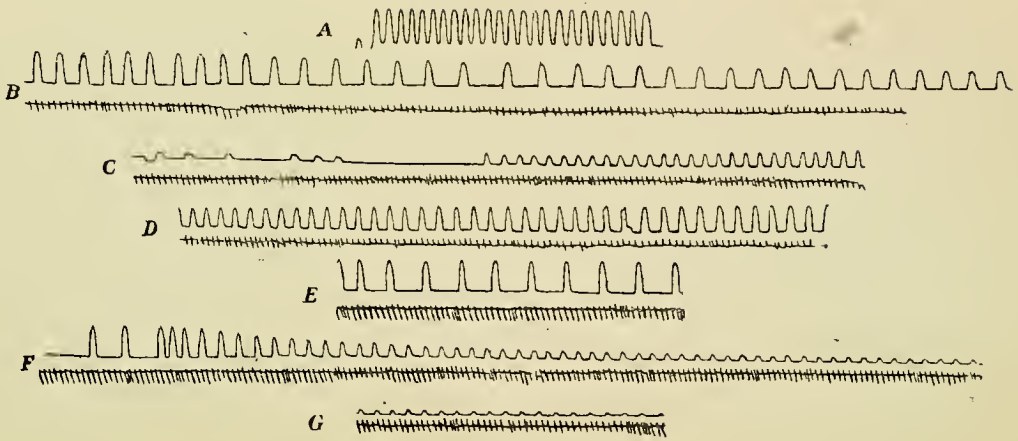

FIG. 10.—CARDIOGRAMS OF FROG'S HEART (EFFECT OF COCAINE).

A. Normal trace.
B. After addition of cocaine.
C. Cocaine removed, nutrient fluid recirculated.
D. do. do.
E. Recovery to normal.
F. Cocaine again circulated.
G. Extreme heart failure—no recovery.

vive the cessation of respiration (Van Anrep). Vagal inhibition is also much depressed and even lost; blood pressure is greatly lowered, though this is preceded by an initial and transient increase of pressure.

Cocaine does, however, produce a very marked depressing action upon the human heart. Many persons after even small doses become pallid and complain of extreme faintness, while the heart's action grows weak and irregular, the radial pulse becoming almost indistinguishable. Blood pressure is lowered. Cocaine in large doses, (and we must remember that what constitutes a large dose varies greatly among different individuals), renders respirations irregular and shallow, and finally will, in dogs, asphyxiate by stopping respiration altogether. In human beings, marked dyspnœa and breathlessness may follow its use.

The nervous system is much affected by cocaine. The peripheral nerves of sense become anæsthetic over the area into which cocaine has been injected, the anæsthesia extending just so far as the drug traverses the tissues. Painting over the skin may, if it be sufficiently thin to permit of absorption, lead to a like result but in lesser degree, since but slight absorption occurs by cutaneous surfaces. The motor nerves are not affected except by large doses. Secretion of saliva is checked, leading to dryness of the mouth and fauces. The other secretions of the alimentary tract are also lessened. Mydriasis is usual among warm-blooded animals.

Although the mind at first will remain clear, there is usually a tendency to garrulity, followed by great anxiety and feelings of unaccountable distress. Languor, muscular weakness, and lassitude, will then take possession of the patient, who becomes haunted by most

fantastic hallucinations. Some persons simply experience slight elation, or may be drowsiness, but loquacity is the most usual symptom.

Cocaine produces at first a slight rise in body temperature.

It is eliminated by the kidneys, and often produces albuminuria or glycosuria, accounted for by Van Anrep as the result of the partial paralysis of respiration, which the drug occasions.

Method of Employment.

Whatever method be adopted, it should be remembered that a dose of one grain will in a large number of persons produce unpleasant if not dangerous symptoms; half a grain is a safer dose, though even this will in many people give rise to trouble.

As a paint, 20 per cent. solution is used, weaker preparations being of little value over cutaneous surfaces. Several coats are necessary, and even then as a rule anæsthesia will not extend much deeper than the true skin.

When used for mucous surfaces, especially if there be any likelihood that some of the solution may be swallowed, a dilution to 10 per cent. should be employed. In laryngoscopic examination Semon uses a 20 per cent. solution, painting the pharynx with it, and this he finds will enable the patient to submit tranquilly to prolonged and painful laryngoscopy.

In ophthalmic practice it is well to instil a few drops of a 4 per cent. solution into the conjunctiva, repeating the instillation two or three times at brief intervals, and then waiting from five to ten minutes before operating.

If the manipulation takes long, it will be necessary to repeat the process from time to time.

Cocaine is also employed in an atomiser, a 4 per cent. solution being used.

Most marked effects, both local and constitutional, follow the use of cocaine when injected hypodermically. Used in this way, its action is more rapid and more persistent than when applied as a paint or an ointment. A 20 per cent. solution is usually employed, and from 2 to 5 minims injected at the site of operation. As the effect may pass off before surgical interference has been completed, it will often be necessary to inject a second or third dose during the operation. From five to ten minutes must be allowed to elapse after injection, before the knife is inserted.

Another and useful method of administration suitable for eye work is the placing of an easily soluble cocaine tablet (B.P., 1885) in the oculo-facial fold of the conjunctiva.

A convenient and very admirable means of using cocaine for a throat spray is the atomiser figured below, invented by W. J. Miller. (Fig. 11).

Dr. Leonard Corning, of New York, proposes yet another method of using cocaine. He first marks out with crayon the superficial veins, to obviate a possibility of puncturing them, and next exsanguinates the limb with an elastic bandage and Esmarch's cord. He then injects superficially three to five drops of a 1 or 2 per cent. solution of cocaine hydrochlorate immediately above the cord. After waiting until the skin is anæsthetic, he injects the deeper tissues with a solution of the same strength, making twenty or more punctures according to the area to be rendered insensitive. Dr. Corning then applies a tourniquet at the upper limit

of the anæsthetic zone, and after a few minutes operates.

This elaborate procedure is based upon the theory that by checking the venous return, he prevents a deportation of the anæsthetic from the area of injection, while dilution of the drug by blood is also lessened.

In other words it is assumed that cocaine, instead of being rapidly absorbed into the circulation, is by this

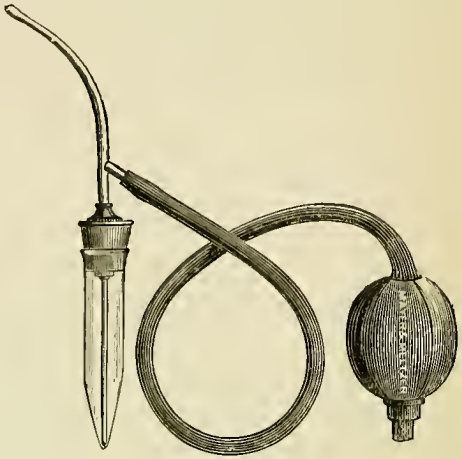

FIG. 11.—Miller's Atomiser.

method able slowly to permeate the tissues and exert its paralysing action upon the peripheral nerve endings. Dr. Corning also employs specially constructed rings and hæmostatic clamps, to effect the same "incarceration of the anæsthetic." The method may prove serviceable when cocaine is used, but, as we have indicated, the employment of frequent and numerous injections of the drug are not devoid of danger. In estimating the

value of this theory also, due regard must be had to the consideration that a limb surrounded by tight cords or a tourniquet, is thus rendered to some extent insensitive, a fact which may account for Dr. Corning finding only small doses of cocaine requisite.

Indications for the use of Cocaine.

Accounts of the effects differ so widely, that it is wholly impossible to do more than indicate the class of cases for which cocaine may be considered as an efficient anæsthetic.

In ophthalmic practice.

Cataract operations.
Removal of foreign bodies.
Laceration.
Iridectomy.
Iridodesis.
Sclerotomy.
Slitting up the canaliculi.

To this list some surgeons add tenotomy for strabismus, and extirpation of the eyeball.

Many minor eye operations have been purposely omitted. Even in the above named cases, cocaine must not be too implicitly trusted, for it fails with some individuals, and no means exist which enable us to determine beforehand when it will succeed or fail. Panophthalmitis has followed its use for eye operations. When employed for extirpation of the globe or tenotomy, instillation is not sufficient, and subconjunctival injection is necessary. In many cases patients complain that the division of the deeper structures causes much pain in spite of cocaine.

Although advocated for operations undertaken to remove foreign bodies from the cornea, etc., cocaine possesses a serious drawback, inasmuch as it induces flaccidity of the eyeball, and so seriously impedes operative measures. In operating for glaucoma, it is necessary to inject cocaine into the anterior chamber to ensure a painless result.

Operations about the Larynx, Pharynx, etc.—

Ulceration of epiglottis, scraping.
Removal of polyps from larynx.
Cutting off the uvula.
Catheterising of the Eustachian tubes.
Removal of polyps from the nose or ear.
Cauterising the nasal meatuses.

Excision of the Tongue has been attempted, but without uniform success.

Abscesses, boils, and carbuncles may be opened, and many of the small operations classed under minor surgery performed, after the injection of cocaine.

Operation on the Urino-generative Tract.—The injection of a few drops of a two per cent. solution into the urethra is said to render catheterisation painless, but this is only true when no stricture exists. In like manner the operations of lithotrity and lithopaxy may be undertaken after an injection of cocaine, a stronger solution (five per cent.) in these cases will better answer the purpose.

In Dental Surgery, Mr. Hern, *Trans. Odont. Soc.*, vol. xix., gives the following list of the uses of cocaine:—

The adjustment of clamps and separators.
The introduction of wedges.
The application of ligatures for the rubber.
The manipulation of deep cervical edges of cavities, whether for excavating, filling, trimming or polishing.

The removal of tartar in pyorrhœa alveolaris.

The modelling of sensitive and irritable mucous membranes. For this purpose a paint of a 10 per cent. solution is used, or a spray of 2 or 4 per cent. according to the degree of sensibility manifested by the parts.

For lancing and excising gum-tissue.

For the relief of pain after extraction, though cocaine is usually inadequate to accomplish this.

For anæsthetising pulps before extirpation.

For obtunding sensitive dentine, (results are not upon the whole satisfactory).

Many observers have come to the conclusion that cocaine is a failure when employed to effect painless tooth extraction; small doses are inadequate, and larger ones too frequently give rise to constitutional derangement which is always prejudicial and often alarming. As a rule, a grain is needed to anæsthetise sufficiently to permit of extraction, and ten minutes must be allowed to elapse before applying the forceps. Many patients are greatly terrified by the pricking of the hypodermic syringe. It is best to inject by three punctures, one on the lingual, and two on the labial aspect of the tooth. One of these being before, and one behind the prominent ridge on the buccal alveolus, they will correspond to the root of the tooth to be extracted.

Dr. George Cunningham and others have published some carefully noted cases in which cocaine used for dental purposes has given rise to very unsatisfactory if not alarming results.

Major Operations.

A few surgeons have undertaken section of bones, clamping of hæmorrhoids, circumcision, etc., but the successes recorded are not such as to justify the use of cocaine in these operations, unless under most exceptional circumstances. In all these cases, repeated and large doses of cocaine have to be injected, and therefore we cannot be sure that most disastrous constitutional effects may not follow. We have moreover to remember, that a conscious patient is always more or less a terrified one, and so not in a favourable frame of mind for surgical proceedings.

Accidents and After-Effects attending the use of Cocaine, with their Treatment.

Severe headache, palpitation, failure of the heart, with repeated attacks of fainting, præcordial pain, and sensation of stiffling and inability to obtain sufficient air, may be experienced after even small doses.

Tingling, formication, muscular weakness, vertigo, and muscular inco-ordination, cold sweats, utter prostration, and extreme drowsiness, are also not uncommon symptoms. Muscular movements almost amounting to convulsions may occur, and in some persons persistent pendulous oscillations of the head follow the use of cocaine, greatly disturbing the operations, (dental), which it was sought to achieve.

Nausea and vomiting sometimes occur, together with cramping pains in the abdomen.

These untoward symptoms may last several hours,

or pass off in less than one; they may be slight, or so serious as to cause the greatest alarm.

One death at least has been recorded from the incautious use of cocaine as a preliminary to a surgical operation. Great caution must therefore be enjoined upon all who undertake prolonged and painful operations under its use.

The most usual *after-effects* are, persistent nausea, headache, anorexia, sleeplessness, derangement of digestion, and great mental depression.

Treatment.—A careful watch being kept over the patient, any signs of heart failure or insufficient respiration must be at once treated. The patient is to be placed on his back, his arms and legs raised, his head hanging below the level of his body, and all clothing loosened about the neck, chest, and waist, while cold air is admitted. If he can swallow, a teaspoonful of sal volatile in half a wineglass of water should be given in sips. Strong smelling salts should be sniffed, the præcordium and front of the chest dashed with a wet cold towel, and sinapisms put to the calves of the legs and nape of the neck. If he cannot swallow, brandy should be rubbed with a finger over the tongue, the inside of lips and mouth. Subsequently, small doses, —half a teaspoonful of brandy—should be given every ten minutes until pallor disappears. Nitrite of Amyl in capsules, or three drops on a handkerchief, may be held to the nose.

Warm tea and hot coffee give a patient comfort after the syncope has passed off, and will also relieve headache.

As a rule, absolute quiet in the prone position, with sal volatile, will bring a patient round without the aid of alcoholic stimulants and the more heroic treatment detailed above.

Should respiration become greatly hampered, artificial means should be at once adopted to maintain breathing.

Cocaine has no distinct *antidote*, although marked physiological antagonism exists between this substance and morphine.

Brucine, and a substance called **drumine** have been suggested as local anæsthetics, but the former is little used, while drumine has been shown to be oxalate of lime prepared from a euphorbiaceous plant and to be devoid of anæsthetic properties.

Other Methods for producing Local Anæsthesia.

The employment of drugs for this purpose may now be said to be confined to that of cocaine; the only other

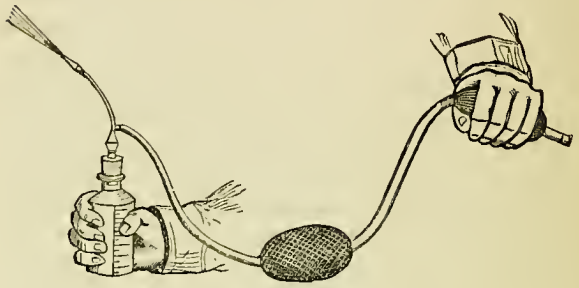

Fig. 12.—Dr. Richardson's Ether Spray.

method which needs comment being that introduced by Dr. B. W. Richardson.

Ether spray.—The woodcut explains the simple mechanism of this useful contrivance. A bottle con-

taining specially prepared ether,* is traversed by an air current propelled by a hand ball so valved as to admit but not allow the escape of air save by its traversing the ether. The second ball, which is covered with net, acts as a reservoir. Air forced into the ether atomises it through a delicate tube, causing it to escape in a fine spray. Ether impinging upon the skin or mucous membrane causes so rapid an evaporation from its surface, that its heat is abstracted with sufficient rapidity to numb the part, thus paralysing the terminals of the sensory nerves.

The anæsthesia is confined to the skin and is very transient. Recovery of sensation when the spray ceases to work, is often accompanied with very painful smarting and tingling. The great detriment of the apparatus is that the instruments and skin get thickly coated with ice which obscures the parts, rendering the use of the knife almost impossible. Further, under ether spray it is difficult to see and secure blood-vessels, and painful to do this when the anæsthesia has passed off. Unless care be taken, the skin may be so much frozen that a slough like that of frost-bite will follow.

Alcohol has been used to produce local anæsthesia. It possesses the property of removing sensation to pain, while tactile sense persists. Alcohol is cooled by placing it in ice and salt, to ten degrees or so below freezing point, and the part to be numbed is then placed in it. The use of alcohol for anæsthetic purposes is not advisable except as a make-shift.

Carbolic acid painted over the skin possesses some benumbing power, but its effect does not penetrate at all

* Richardson recommends anhydrous ether, sp. gr. 0·720, mixed with an equal part of hydride of amyl (Rhigolene).

deeply, and is disadvantageous inasmuch as the tissue touched is damaged by the caustic action of the acid.

Faradic currents directed for some minutes through an area of skin or mucous membrane, are held by a few to produce anæsthesia. At one time this method was in vogue among dentists; it has now justly fallen into disuse.

Rhigolene, a product of the distillation of petroleum, was introduced by Richardson, who employed it instead of ether in his atomising spray. Rhigolene has a sp. gr. of ·625; it is one of the most volatile substances known, and so needs to be kept in strong, well-stoppered bottles.

The uses and precautions described under the head, "Local Anæsthesia—Ether" apply to rhigolene.

Bisulphide of carbon, although an effectual local anæsthetic, when used from a spray or by irrigation possesses the insuperable disadvantages of having a disgusting odour and of being a potent poison.

CHAPTER XII.

Medico-Legal Aspects of the Administration of Anæsthetics.

The administration of an anæsthetic to a patient who is not a minor, against his will, constitutes an assault. When a patient has voluntarily submitted himself to be anæsthetised, he may under the influence of terror during an early stage of the proceedings attempt to prevent further narcosis; he is then not sufficiently under control of his reason, and the administrator is bound to take his own course in the patient's own interests.

The anæsthetist, like any other medical man, is liable to prosecution for malpraxis; it then rests with him to prove that whatever steps he took were adopted after due consideration and because he believed them to be the best he could follow for the benefit of his patient. Such questions as the following might arise:—Did the anæsthetist undertake a duty which knowledge, skill, and experience had qualified him to fulfil? Did he employ the most suitable agent according to his view of the exigencies of the case? and did he administer it with due skill and after the most approved method? Did he possess himself of all necessary facts with regard to the patient's bodily condition? and did he make due allowance for these in the treatment which he pursued? And, in the event of an accident of any kind, did he adopt the right and appropriate treatment indicated in such an emergency? and was this done with due promptitude?

Anæsthetics have been employed to assist in the perpetration of various crimes upon the person narcotised. Thus, an anæsthetic may be given, it is alleged, without the consent of a person; or when given with his or her consent to effect a lawful procedure, advantage may be taken of the anæsthetised person's helpless condition to perpetrate a crime.

Can an anæsthetic be administered without consent?

Firstly, can this be done whilst a person is awake and in full possession of his senses? Formerly many cases came into the law courts in which the complainant alleged that a handkerchief saturated with chloroform was waved before his face and unconsciousness followed *immediately*. This we now know to be an impossibility; a period of time varying from two to twelve or more minutes must elapse before an individual succumbs to chloroform, and during this time fresh supplies of the anæsthetic would be needed. Further, chloroform in most cases produces so much excitement, that one person would find it a difficult matter to keep the victim sufficiently still to complete the anæsthesia, and would hardly do so without much noise and disarrangement of the victim's clothing. Further, unless food is avoided before the anæsthetic is given, vomiting is very liable to occur, and with it a return to consciousness.

It is often alleged by the supposed victim that he, or she, was conscious of what was transpiring, but was powerless alike to speak or resist. Such statements must be received with the utmost caution. It is true that Péan records cases in which patients though rendered analgesic by ether, retained their consciousness as to what was in course of proceeding. Cases like Péan's must be so exceptional that one is tempted to believe the anæsthetic was administered very imper-

fectly, and that faith in the assurance of the surgeon did the rest. Snow also admits the possibility of persons imperfectly chloroformed being conscions and yet powerless to resist. In attempts at criminal violence under an anæsthetic administered withont the victim's consent—fear, excitement, and struggles, wonld all be against the possibility of arriving at analgesia without deep narcosis. It is very doubtful whether a person, be he an expert or not, conld narcotise a waking adult against his will unless there existed a very unusual disproportion between the strength of the two individnals. In the case of R. *v.* Snarey, the prosecntrix alleged that she had been rendered insensible instantly by something being held over her face upon a handkerchief, and in that condition she had been violated. This contention conld not in a present state of knowledge be admitted by experts. However, in a parallel case, that of White *v.* Howarth, the prosecntrix made a similar assertion, and added that she was aware of what was going on bnt was nnable to resist.

Althongh the time required to thoroughly anæsthetise a patient is longer when chloroform is nsed than when ether is employed, yet, from the highly irritating natnre of ether vapour it is less easy to administer to an unwilling patient than chloroform. And further, it requires the nse of some apparatus entirely excluding air, and is hence less easy to manipulate by non-experts. In general it may be affirmed, that if chloroform can only be used for criminal purposes with difficulty, still less easy wonld prove such attempts under ether.

Can a Person be Anæsthetised during Sleep?

Dolbeau made careful experiments with reference to this subject, and his conclusions are certainly consonant with the experience of most skilled anæsthetists.

He first attempted to anæsthetise four persons during sleep. Three were awakened in the process. In his second series of cases four persons out of six awakened, and in his third series only three persons awakened out of nine to whom he administered chloroform while sleeping. Dr. Turnbull asserts that either chloroform or ether may be given during sleep without awakening the subject of the experiment. I have no doubt that chloroform may in many cases be so administered, but am less sure about ether; in either case certain conditions must be present to ensure success. Only the greatest care, skill, and familiarity with the anæsthetic used would suffice, and then we must predicate the subject to be a sound sleeper. But it is highly improbable that a novice in anæsthetics would succeed in such an attempt.

A further question arises upon which evidence may be sought, and that is whether it is possible to prove the person attempting to administer an anæsthetic with criminal intent was one skilled in its use. To determine this offers some difficulties. The presence of apparatus, the method in which lint or a handkerchief is folded, or blistering of the lips and nose from allowing the chloroform to drop upon the face—may offer a clue. If ether be employed we may be sure that the person using it possessed some knowledge, and had resort to an apparatus, since ether given by the open method

seldom if ever carries the patient beyond a stage of delirious excitement producing bellicose struggles such as would effectually prevent the accomplishment of any criminal design.

Anæsthetics have been given to assist in the committal of ROBBERY, RAPE, and MUTILATION. What has been said above leaves little to add with regard to robbery.

ATTEMPTED RAPE UNDER ANÆSTHETICS.

Many cases have now been reported in which the prosecutrix has affirmed that a dentist or surgeon has violated her person while she was under the influence of an anæsthetic. So frequent are such charges that the greatest care should be taken on the part of the operator in order to ensure the presence of a third person, at least within ear-shot, and preferably within sight of the administration. No administrator of an anæsthetic is safe from having such a charge preferred against him, and if he and his supposed victim are alone, it is simply a case of word against word. Further, the woman may be enceinte at the time of the alleged rape, and may subsequently give birth to an infant whose parentage she may find it convenient to fasten upon the medical man.

But it is not only designing bad women who bring such charges. Modest, virtuous, and refined gentlewomen have been prosecutrices in these cases. The cause for this remarkable and deplorable state of things is fortunately not far to seek. Chloroform, ether, nitrous oxide gas, cocaine, and possibly also the other carbon compounds employed in producing anæsthesia,

possess the property of exciting sexual emotions, and in many cases produce erotic hallucinations. It is undoubted that in certain persons sexual orgasm may occur during the induction of anæsthesia. Women, especially when suffering from ovarian or uterine irritation, are prone to such hallucination, and it is almost impossible to convince them after their recovery to consciousness that the subjective sexual sensation is not of objective existence. A case cited by Dr. Richardson, will illustrate this statement. A young lady had chloroform administered to her by the doctor in the presence of a dentist and of the young lady's mother and father. After the tooth had been extracted, and the patient became conscious, she steadfastly affirmed that she had been criminally assaulted by the dentist, and to this statement she adhered although the four persons present in the room strove to disabuse her mind.

In considering the evidence in such cases the following points need especial attention :—

Nature of the anæsthetic.—Chloroform, ether, and the other members of the carbon anæsthetic series certainly render a person wholly unable to protect himself from any personal ill-usage. The body of the anæsthetised patient is, however, rendered utterly flaccid, and is a dead weight. If then there is any question of moving the body, as for example, from a dental chair, and again back into the chair, it must be remembered that such an undertaking would be exceedingly difficult for one individual however strong, and could hardly be accomplished without causing much disarrangement of clothing.

On the other hand if the offence was alleged to have been committed when the patient was under the

influence of nitrous oxide gas, it would have to be borne in mind that the effect of this gas is to produce first muscular rigidity and subsequently violent jactitation. Further, unconsciousness only persists from half to one minute, or in exceptional cases one minute and a half, and the patient regains her senses with control over her muscles all at once. This being so it is exceedingly improbable that even a premeditated and skilfully planned attempt at violation would be successful if made under nitrous oxide gas.

A caution is needed about admitting the evidence of a person only just recovered from an anæsthetic. The following case illustrates this :—A dentist appealed to a friend to extract a tooth. Under gas he struggled so violently that the operation was not performed, but as he came to, he reproached his friend most bitterly, telling him he had felt the whole pain of the extraction and was even then suffering torture !

Death under an Anæsthetic.

It becomes requisite to decide whether the death was suicidal, accidental, or due to an anæsthetic given by a second person, and then whether that person was an expert or not. Persons frequently employ chloroform as an anodyne, and many deaths have resulted from the stopper coming out of the bottle, the contents escaping upon the patient's pillow. The presence of a phial near the corpse might point to self-administration. Ether is not used similarly, and is not selected by suicides. One death from nitrous oxide gas is recorded from America. A dentist whilst under the influence of drink, placed himself in his chair and turn-

ing on the gas held the face-piece over his mouth and nose. In the morning he was found dead and the gasometer empty.

It is important to carefully search for evidence as to *how* the anæsthetic was administered, as this may determine whether it was done *secundum artem* or unskilfully.

The enquiry into a death supposed to be from an anæsthetic, commences with the question—was it due to the narcotic, or to hæmorrhage, shock, exhaustion, or some other mischance following surgical interference? The mode of death due to chloroform, ether, and other agents is described under the heading *chloroform*, etc.

The CHOICE of the ANÆSTHETIC would have to be JUSTIFIED; thus, were chloroform given for a simple tooth extraction in lieu of the safer agent nitrous oxide gas, and were the patient to succumb, the administrator could with reason be severely censured for subjecting his patient to such an unnecessary danger.

All anæsthetics are dangerous. In the hands of one skilled in their use this danger is minimised; but whatever may be individual uses and opinions, the general consensus of belief places anæsthetics in the following order of safety:—nitrous oxide gas when used for short operations; ether; chloroform. Other substances are not used sufficiently often to make statistics reliable, but the following table gives a rough estimate of their danger.*

* No stress can be laid upon such figures, as in many cases a death occurred very early in the career of an anæsthetic, and this rendered further trials of it inadvisable.

TABLE SHOWING DEATH-RATE UNDER THE VARIOUS ANÆSTHETIC BODIES.

	Deaths.	Administrations.
Chloroform (Coles, Virginia)	52 in	152,260
,, (Richardson) ...	1 ,,	2500 to 3000
Ether (Andrews)*	1 ,,	23,204
Nitrous oxide gas	1 ,,	100,100
Amylene	2 ,,	238
Hydrobromic ether	2 ,,	(?)
A. C. E. Mixture, No. not ascertainable†		
Methylene mixture*	1 ,,	5000
Vienna mixture	(?)	

It must be added that Scotland presents a series of statistics much more favourable to chloroform; thus out of 36,500 administrations at the Edinburgh Infirmary during ten years, only one death has been recorded.

Inquiries recently made have revealed that several deaths from chloroform have occurred at the various surgical centres of Scotland, so that the above estimate can no longer be taken as a reliable statement of the death-rate from chloroform.

Questions of responsibility when the patient dies under an anæsthetic may involve those as to whether the most suitable anæsthetic was given to him. Sometimes a patient refuses one anæsthetic, preferring another; here the administrator clearly cannot shirk responsibility, but must give that agent which he deems best, without regard to the whim of the patient. In

* Probably too low an estimate.

† Richardson states erroneously that no death has occurred under A. C. E. mixture.

the converse case when death occurs during the administration of an anæsthetic which the patient declined to take until persuaded, cajoled, or cheated into so doing, the anæsthetist would have to show that his special knowledge guided him in making his selection, which although ending untowardly, was in point of fact, the best he could effect. In the employment of a new or untried anæsthetic, very grave responsibility would rest with the administrator unless he very fully and clearly explained the possible results, and obtained the patient's consent to the experiment.

A question which we have not yet considered arises—who in the eye of the law is qualified to administer an anæsthetic? At present some uncertainty exists upon the point owing to discretionary power being left to the operator to assume the so-called responsibility of the anæsthetic. Thus butlers, coachmen, dispensers, and various unqualified persons are frequently permitted to give the anæsthetic, or as the phrase is, "keep it going," while the surgeon besides operating is supposed to exercise a general supervision over the administrator's proceedings. If any accident happens, the certificate is duly signed by the surgeon, and the coroner's court admits the principal's evidence. It cannot be doubted that to give any individual an anæsthetic subjecting him to a minimum of danger is all one person can do, and can only be accomplished by those specially instructed and experienced in anæsthetics.

Were an action for damages raised upon a death occurring under the above named circumstances, there is little doubt that the persons proceeded against would be heavily mulcted, since nothing short of the utmost emergency could justify the proceeding.

How far dentists practising with or without the

L.D.S. diploma are legally justified in administering anæsthetics is a moot-point. Many hold that the L.D.S. confers a right to the administration of nitrous oxide gas, but no other form of anæsthetic. In the United Kingdom no trial case has, I believe, been contested. The ground for this affirmation that licentiates in dental surgery possess such a right, has no legal basis, but has grown out of a belief that the use of nitrous oxide gas is part and parcel of the dentist's business, and that so he has a right to employ it. This, however, applies with equal force to all registered dental practitioners. Probably the issue would hinge in the present ambiguous condition of the law, rather upon the previous experience and recognised skill of the person administering the anæsthetic, than upon bare qualification. Thus, could it be shown that a registered practitioner, after two or three thousand successful administrations, met with an accident, in spite of all due care and precaution, he would probably be in a better position than would a well-qualified practitioner, who met with a fatality presumably through mal-adroitness, if it were shown that he had never obtained a practical experience in anæsthetising.

In any case a person would be open to grave censure, if not liable for malpraxis, were he to undertake the administration of an anæsthetic, and operate single-handed, unless it could be shown that to do so was a necessity, no help being accessible.

Death from Nitrous Oxide Gas.

The deaths which have occurred when the patient had inhaled or was inhaling the gas, cannot be imputed

to any specific action it exercised. In some cases heart failure occurred upon the patients resuming consciousness *before the operation was completed*, and in others respiration was interfered with by gags slipping and setting up laryngeal spasm. Unquestionably there is danger if the patient is allowed to feel pain, especially in operations upon the fifth pair of nerves, but little if any when the gas is given fully and the operator warned to desist before consciousness returns.

The P. M. appearances are simply those of death from syncope, or death from asphyxia.

Death from Ether.

If viewed before death, the individual will be found to be lethargic or comatose, breathing slowly, deeply, and with stertor, the skin pale and cold and covered with clammy sweat. The exposed mucous membranes will be purplish; the face livid; the pulse quick, soft, small, and compressible. Complete muscular relaxation gives the body a flaccid doughy feel. The eye is fixed and glassy and usually smeared with a thick film of mucus, the pupil is dilated and insensitive to light. The body temperature is depressed several degrees below normal.

If the vapour has been inhaled, a much smaller dose is needed than when ether is swallowed. The effects given above may be brought on in from three to five minutes. Six drachms to an ounce are necessary to produce narcotism when swallowed.

Post-mortem appearances.—If examined within twenty-four hours after death, the brain, lungs, liver, spleen or kidneys, upon being cut give a strong ethereal

smell. The blood is dark, and thick although still fluid. The lungs are congested posteriorly and filled with aërated spumous fluid in front (Taylor). The bronchial mucous membrane is reddened from injection throughout its entire extent. The cerebral and spinal vessels are found congested, and the meninges stained.

Ether when swallowed has not caused death in the human subject (Taylor). Orfila, experimenting upon dogs, found the mucous membrane of the stomach of a blacky-red colour, acutely inflamed by a lethal dose of ether.

The duodenum was also red and inflamed, the heart contained black blood which was partly coagulated.

The detection of ether by analysis.—Ether in liquid is distilled from the stomach contents and led through a glass tube containing asbestos moistened by a mixture of sulphuric acid and saturated solution of bichromate of potash. The asbestos turns green.

Its odour is also characteristic; ether burns with a smoky yellow flame; it is only slightly soluble in water.

The tissues.—In recent examinations the odour is characteristic. Since but little ether is absorbed by the blood, and of this little some is converted into aldehyde, (Taylor) it is almost impossible to separate ether from it or the solid tissues by distillation.

Death from Poisoning by Chloroform

May occur through inhaling the vapour or drinking the fluid. If examined before death, the individual will be comatose, breathing stertorously with slow, shallow respirations. The skin will be cold and blanched, the face livid, the lips ashen in hue, the pulse imperceptible,

and the pupils may be widely dilated, but insensitive to light. Muscular flaccidity is present, but epileptiform convulsions often occur.

Post-mortem appearances.—In cases of deaths from chloroform the appearances reported vary very much, and this is probably due to the confusion present in the minds of many persons concerning the connexion of cause and effect. Thus death from asphyxia, fear, shock, and so on, are attributed to chloroform; and further, the autopsies are seldom made soon enough to be of any value, while sufficient note is seldom taken of the stage in which death occurred. We should expect the cadaveric appearances presented in the first stage to differ widely from those found in the last stage, and yet in but few records have I been able to find any information bearing directly upon this point.

In the earlier stage chloroform congests the vessels of the brain and cord, and so this condition, although inconstant, is sometimes found.

The lungs are usually deeply congested, the heart empty, flaccid, or containing a little fluid blood. In some cases the right heart is full even to distension, of dark fluid blood (asphyxia). The blood remains fluid, it is very dark and is said occasionally to contain bubbles of gas (Taylor). Snow, analysing thirty-four cases, describes visceral engorgement, but in some instances he found the lungs normal. Casper denies that any of the features pictured above are pathognomonic of chloroform poisoning. When the drug is swallowed it produces gastro-enteritis, and pathological appearances resulting from this would be seen post-mortem.

Detection of chloroform.—The odour very soon passes off. Dr. Taylor failed to detect any in the blood half an hour after administration. Analysis of

the blood also fails to reveal any evidence after half an hour.

Analysis of the tissues.—The substance supposed to contain chloroform is placed in a flask, one end of which is in a hot-water bath, the other communicating with a tubulure which is heated by a flame. The bath is raised to 160° while the tube is heated to redness. Chloroform vapour driven off by the heat of the water bath is split up as it traverses the tube, chlorine and hydrochloric acid being set free. The vapour reddens blue litmus, precipitates solutions of nitrate of silver, and liberates iodine from iodide of potassium which is tested in the usual way with starch paper.

Self-Indulgence in Anæsthetics.

A "habit" has been unhappily created for most forms of anæsthetics. Thus, some persons become addicted to self-administration of chloroform; others to that of ether; others again to that of chloral; while cocaine also has its victims. It is not within the scope of the present work to describe the proper modes of treating the slaves of such unfortunate habits, but merely to draw attention to them, that medico-legal questions arising out of such depraved practices may receive due notice. Nitrous oxide gas although presenting greater difficulties to self-administration, has yet led some weak principled persons to practice self-induction of anæsthesia by its aid.

The possibility of the subject of an inquiry—in cases of supposed suicide or murder by anæsthetics—being an

habitué of one of them, should not be allowed to drop out of mind.

Insanity following the Administration of Anæsthetics.

Among persons predisposed to insanity the administration of anæsthetics may in certain rare cases determine an attack of mania. "It is the fact of the temporary disturbance of function, and not the means by which this is produced which is of most importance." (Savage). It is stated upon the high authority of Dr. Savage that chloroform, ether, nitrous oxide gas, and indeed any anæsthetic is capable of so interfering with brain functions, that the delirium of commencing narcosis may become reproduced upon the patient's recovering from the sway of the anæsthetic, and may either persist as intractable mania or pass off after expending its violence in a sharp but transient maniacal seizure. The possibility of such a result ensuing upon the administration of an anæsthetic to a person either highly neurotic or coming from a family in which insanity had been developed, should be borne in mind when such individuals are examined with a view to ascertain their fitness for anæsthetisation.

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